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Only the numbers listed below have been retained:

1201	1229
1218	1231
1222	1232
1223	1235
1225	1238
1227	1243
1228	1249

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CONTENTS

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Washington, D. C. March 19, 1924

PLANTS TESTED FOR OR REPORTED TO POSSESS INSECTICIDAL PROPERTIES

By

N. E. McINDOO, Insect Physiologist, Fruit Insect Investigations, Bureau of Entomology, and A. F. SIEVERS, Chemical Biologist, Office of Drug, Poisonous, and Oil Plant Investigations, Bureau of Plant Industry

CONTENTS

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PLANTS TESTED FOR OR REPORTED TO POSSESS INSECTICIDAL PROPERTIES.[1]

By N. E. McIndoo, *Insect Physiologist, Fruit Insect Investigations, Bureau of Entomology,* and A. F. Sievers, *Chemical Biologist, Office of Drug, Poisonous, and Oil Plant Investigations, Bureau of Plant Industry.*

CONTENTS.

ECONOMIC ASPECTS OF PLANT INSECTICIDES.

The search for commercially valuable insecticides in the plant kingdom has two phases. The testing of the material to determine its effectiveness constitutes the first phase. After extensive laboratory and field tests have proved it to have sufficient merit, it then becomes necessary to determine the practicability of obtaining commercial quantities of the material and to make it available in proper form for insecticidal purposes. This constitutes the second phase.

Several factors must be considered in determining the practical availability of a plant insecticide. Among these may be mentioned (1) habitat, whether foreign or domestic, and whether wild or culti-

[1] The Bureaus of Entomology and Plant Industry in 1915 began a cooperative project which included a careful study of the physiological effects of the plant insecticides and a search for new insecticides in the plant kingdom. At the outset a search was begun for plants which would furnish materials for efficient insecticides. This bulletin embodies most of the unpublished results of this study and also includes as complete a catalogue as possible of all plants that have been tested for or reported to possess insecticidal properties. Some of the plant material used in this work has come from foreign countries, but the majority of the samples are from the United States and its possessions. Many persons, chiefly employees of the United States Department of Agriculture, who are widely scattered over the world, have sent much of this material. The scientific and common names, families, and habitats of the plants discussed have been verified by Drs. S. F. Blake, Frederick V. Coville, and W. E. Safford, all of the Bureau of Plant Industry.

vated; (2) characteristics of growth, whether annual or perennial, large or small, abundant or sparse; (3) portion of the plant effective; and (4) nature of the active constituent and the means necessary to make it available for use.

The most desirable type of plant is no doubt one which grows abundantly in a wild state, preferably in areas not readily adapted to the cultivation of valuable crops. Under such conditions the material could be obtained with the minimum of expense, the only cost being that of collection and preparation. Less abundant growth involves greater cost in collecting, and in case the plant must be cultivated it must bring sufficient return to compete with other crops adapted to that particular region. Perennials are much more desirable than annuals, since their products can usually be collected from year to year. Leaves and branches of trees or shrubs or the entire herbaceous portions of hardy perennials can be most economically obtained. On the other hand, the collecting of fruits or seeds or the digging of roots or rhizomes can, as a rule, be much less economically done. In the case of small plants, gathering the roots usually means the destruction of the plant, which, in time, is likely to reduce the supply unless the plant is under cultivation.

The character of the active constituent has an important bearing on the handling necessary in its preparation for the market. Substances like alkaloids and toxic resins are usually not subject to ready decomposition, and material containing such constituents need not be dried and handled with more than ordinary care. On the other hand, plant material depending for its action on glucosides must be carefully dried in order to inhibit decomposition of such constituents. In the case of plants native to foreign countries, especially the Tropics, this is an important matter, since the collecting is usually done by natives, and control of conditions of handling is likely to be difficult. Long voyages, especially by sea, are furthermore likely to cause deteriorating changes in such plant materials.

It is evident, therefore, that the search for a plant which may be made commercially available as an insecticide at a reasonable price extends much farther than merely finding a plant which possesses insecticidal properties to a satisfactory degree. It involves, in addition, a study of the botanical characteristics of such a plant, its habitat, the available natural supply, the means necessary for its proper collection and shipment, and, above all, the cost at which it can be delivered to the manufacturers in this country.

METHODS USED BY THE WRITERS IN PREPARING PLANTS FOR INSECTICIDES.

To determine the insecticidal properties of plant material, a number of different ways of preparing it are necessary. This is especially true if the material is of unknown composition. Tests on insects may be made by applying the material (1) in a dry, finely ground condition as a dusting powder; (2) in the form of water extracts made with hot or cold water; or (3) as extracts made with other solvents, such as benzene, gasoline, petroleum ether, and alcohol. In all cases the material must be thoroughly dry, and then be reduced to a powder. If the powdered material is to be used as such

for dusting it should be very fine, at least fine enough to pass through a sieve having 60 meshes to the inch. If it is to be extracted such fineness is not always necessary. Cold-water extracts are best prepared by macerating the material in water for several days or longer, then filtering or straining, and making the aqueous extract up to the desired volume with more water. The cold-water method is necessary in the case of material which will decompose if heated. Decoctions, or hot-water extracts, are best made by boiling the ground material with water or percolating boiling water through it. These extracts may be concentrated, if necessary, to any desired volume by evaporating under reduced pressure (less than one atmosphere) on a steam bath. Plant material which can be used with satisfactory results as a powder or as a water extract may be sold in the powder form, with directions for use, because the preparation of the water extract, either hot or cold, is a simple process.

In many cases, however, the plant constituent which has the desired insecticidal effect can not be removed with water, but requires some organic solvent to effect its solution. In these cases the plant material is macerated or percolated with the desired solvent, either with or without heat, according to the nature of the active constituent. From the extracts obtained the solvents must be removed by distillation under reduced pressure. The concentrated extract must then be incorporated into a watery spray mixture. Since extracts made by means of alcohol, benzene, gasoline, or other organic solvents are usually insoluble in water, a special procedure is necessary to make a spray solution in which the organic extract is held in a fine and fairly stable suspension. The best method must usually be determined by trial for each individual case. In most cases the semisolid extract can be triturated with soft soap and water gradually incorporated so that a suspension of finely divided but undissolved particles results, giving the spray mixture a milky or muddy appearance. Frequent shaking will keep the mixture uniform in the sprayer.

INSECTS EMPLOYED AND METHODS OF TESTING PREPARATIONS AGAINST THEM.

In all, 28 species of insects were tested—the squash lady-beetle (*Epilachna borealis* Fab.) and Colorado potato beetle (*Leptinotarsa decemlineata* Say) belonging to the Coleoptera; the house fly (*Musca domestica* L.) to the Diptera; the following 17 species of aphids to the Hemiptera: *Aphis* spp. called *A*, *B*, *C*, *D*, and *E*, cabbage aphis (*A. brassicae* L.), green apple aphis (*A. pomi* DeG.), nasturtium aphis (*A. rumicis* L.), *A. spiraecola* Patch, *Macrosiphum* spp. called *A*, *B*, and *C*, tulip-tree aphis (*M. liriodendri* Mon.), rose aphis (*M. rosae* L.), potato aphis (*M. solanifolii* Ashm.), chrysanthemum aphis (*Macrosiphonella sanborni* Gill.), and green peach aphis (*Myzus periscae* Sulz.); the honeybee (*Apis mellifica* L.) and sawfly larva (*Neurotoma fasciata* Norton) to the Hymenoptera; the silkworm (*Bombyx mori* L.), catalpa caterpillar (*Ceratomia catalpae* Bdv.), fall webworm (*Hyphantria cunea* Dru.), and tent caterpillar (*Malacosoma americana* Fab.) to the Lepidoptera; and the roach or croton bug (*Blattella germanica* L.) and grasshoppers (*Melanoplus femur-rubrum* DeG.) to the Orthoptera.

Potato-beetle larvæ.—Larvæ of the potato beetle were collected on potato plants and when brought to the laboratory were placed in cheesecloth cages, 9 inches square by 12 inches tall. The larvæ were so well mixed before they were placed in the cages that each cage contained about the same number in the various instars. Sprayed or dusted potato-plant foliage was given to them daily. Parasitism was common only among those in the last instar.

House flies.—Flies were reared in specially constructed screen-wire cages, 12 inches square by 18 inches tall, each of which contained one-half gallon of moist bran mash. The females readily oviposited in this mash, which later served as food for the larvæ and which proved a good substitute for manure. Large numbers of flies were thus reared, some of which were fed poisoned food in these cages, while others were transferred to small observation screen-wire cages in which they were dusted with powders.

Aphids.—Some of the aphids tested were sprayed or dusted outside the laboratory, but most of them were treated inside the laboratory in a manner similar to that described in another paper (*60, p. 508*).[2]

Honeybees.—Twenty young worker bees of practically the same age were placed in each of many screen-wire experimental cages and were fed in a manner similar to that described in another publication (*61, p. 181*). The sawfly larvæ were treated as described for aphids.

Silkworms.—Silkworm larvæ were reared in the laboratory and were fed leaves as follows: Mulberry-tree leaves were dusted or sprayed with the various preparations and with tap water (used as a control), an atomizer being used in all the spraying experiments. The leaves after having been dried in the air were cut into small strips which were then placed in small screen-wire cages. An effort was made to put approximately the same amount of food in each cage, so that a rough comparative estimate of the food consumed could be made; this procedure was also followed while feeding the other species of chewing insects. Ten normal silkworms, all of practically the same size and not ready to molt, were put in each cage. Counts were made daily (except on Sundays), the cages being cleaned and treated food being renewed at the same time. No disease was noticed among these larvæ.

Fall webworms.—Webs of the fall webworm were collected in the fields on Monday from a variety of plants; after being brought to the laboratory, these webs containing the webworms were kept in large cages with a small amount of food till Tuesday noon, by which time the larvæ were well mixed according to size (all instars but the first one), and by this time they were very hungry. Tuesday morning approximately the same amount of mulberry-tree foliage was placed in each of several wide-mouthed bottles containing water; it was then sprayed or dusted, and when the foliage was dry each bottle with contents was placed in a large battery jar, 8 inches in diameter by 12 inches tall. Tuesday afternoon an effort was made to place approximately the same number of webworms in each jar,

[2] The figures (*italic*) in parentheses refer to "Literature cited," p. 54.

and dusted or sprayed food thereafter was renewed daily. Thus by starting each set of experiments on the same day of the week, the days (Sundays) on which no records were taken always fell on the fifth, twelfth, and nineteenth days of the tests. Very little disease was noticed, and parasitism was not bad among these larvæ.

Tent caterpillars.—Tent-caterpillar tents were collected in the fields from wild-cherry trees, and were later handled as already described for the webs of webworms. Dusted or sprayed wild-cherry-tree foliage was placed in the jars daily and counts were made daily as usual. Owing to the prevalence of the "wilt" or polyhedral disease, it was necessary to test these larvæ while they were in the earliest instars, because during the last instar they were badly diseased.

Catalpa caterpillars.—Catalpa caterpillars were collected on catalpa trees, and when transferred to the laboratory were treated as described for the webworms and tent caterpillars.

Roaches.—These insects were reared in a specially constructed roach box which was very suitable for the purpose. On various dates 20 or 25 were put in each of several small screen-wire cages in which they were dusted or fed poisoned foods.

Grasshoppers.—Grasshoppers in the fourth, fifth, and sixth (adult) instars, caught in the fields, were either fed poisoned bran mash in the cheesecloth cages, already described, or were dusted in the small screen-wire cages.

Fumigating tests.—The insects to be tested were put in the large battery jars, 8 inches (20.32 centimeters) in diameter by 12 inches (30.48 centimeters) tall, each with a capacity of about 9.8 liters; then a 1-gram cone of powder was placed in each jar; next the powder was ignited; and finally a glass cover, almost airtight, was placed over each jar.

RESULTS OBTAINED BY THE WRITERS.

The writers have tested 232 preparations from 54 species of plants (not including tests of which the results have already been published) against a total number of 28 species of insects. Some of the more important results obtained are recorded in Tables 1 to 8. The plants first discussed are arranged alphabetically by genera, but under the subheading "Comparative results discussed" this arrangement is not maintained, although it is for the remainder of the discussion under the heading "Discussion of the less important results obtained."

For a more complete account of the species of plants discussed, the reader is referred to the "Catalogue of plants tested for or reported to possess insecticidal properties" and to the "Index of botanical and common names of plants catalogued."

DISCUSSION OF THE MORE IMPORTANT RESULTS OBTAINED.

AMIANTHIUM OR CROW POISON.

The writers obtained the following results by using amianthium or crow poison (*Chrosperma muscaetoxicum*). The powdered bulbs

and leaves (Nos. 33*a*, *b*, and *f*, each used as a dust) were efficient but slow against roaches, grasshoppers, flies, and bees (Table 1), but inefficient against *Aphis* spp. *A* and *B* (Table 2), and had little effect on tent caterpillars. Used as a stomach poison, these powders were efficient against grasshoppers, silkworms, and flies (Table 1), but had no effect on large webworms.

The water extracts (highly concentrated) from the leaves and bulbs of amianthium, each sprayed upon the insects and their food, had considerable effect on roaches, potato-beetle larvæ, and silkworms, but none on webworms, potato aphids, rose aphids, and *Aphis* spp. *A* and *B* (No. 35fa, Table 3). The alcoholic and benzene extracts (Nos. 504 and 513, Table 4) from the bulbs, used with soap, were inefficient against four species of aphids (*Aphis* spp. *A* and *B*, *Macrosiphum* spp. *A*, and *M. liriodendri*). The alcoholic extract, however, was efficient against silkworms.

At Vienna, Va., three apple trees, each bearing a nest of tent caterpillars from one-half to three-fourths grown, were selected for preliminary field tests. One tree was sprayed with a 10 per cent solution of a water extract from the leaves of amianthium; another tree with a 10 per cent solution of a water extract from the bulbs; and the third tree served as a control. A week later the caterpillars on the sprayed trees appeared shrunken and apparently had not eaten since the trees had been sprayed. The caterpillars on the control tree and others near by were almost full grown.

INSECT POWDER OR PYRETHRUM.

The following results were obtained by using a commercial insect powder, here called pyrethrum, and probably derived from *Chrysanthemum cinerariaefolium.* Most of the details will be given when comparing these results with those obtained by using certain other plants (see pp. 10 to 21). The powders (Nos. 103 and 503, Table 2), used as dusts, were found efficient against five species of aphids (*Aphis* spp. *A* and *B*, *Macrosiphum* spp. *A* and *B*, and *Macrosiphonella sanborni*), grasshoppers, silkworms, flies, potato-beetle larvæ (Table 1), and tent caterpillars; used as a decoction, not filtered (No. 103a, Table 3), it was efficient against *Aphis* spp. *A* and *B*, but used as a hot-water extract (filtered, No. 103b), it had no effect on these insects; used as a fumigant (No. 103), it was efficient against *Macrosiphum* sp. *C* and *Myzus persicae*, silkworms, webworms, and a ladybeetle tested. The hot-water extract (filtered) and a distillate were efficient against silkworms, but the cold-water extract (filtered) was inefficient.

The alcoholic and benzene extracts, when sufficiently strong and used with soap or kerosene emulsion, were found efficient against aphids (Tables 4, 5, and 6). The alcoholic extract, used with soap, was efficient against small webworms (first instar) and half-grown sawfly larvæ, but only about 50 per cent of the larvæ and none of the adult potato beetles tested were killed within seven days.

"CUBE."

In 1920, while collecting fishes in Peru for Indiana University, Dr. W. R. Allen procured a supply of the dried roots of "cube" (see footnote on p. 34); some of these were used as a fish poison and

the others were brought home. The latter were afterwards ground and some of the powder was sent to the writers by Dr. C. H. Eigenmann, who was in charge of the expedition to Peru and Ecuador.

According to a letter from Doctor Allen, "cube" or "barbasco" is a woody shrub whose roots contain a milky sap of a very poisonous character. In Peru the sap is used as a wash for cattle to kill ticks and the roots are unlawfully employed to poison fish in streams. (See pp. 10 to 20.)

The following results were obtained by using "cube." The powder (No. 501), used as a dust, was efficient against potato-beetle larvæ (Table 1) and four species of aphids (*Aphis* spp. *A* and *B*, *A. rumicis*, and *Macrosiphum solanifolii*, Table 2), but inefficient against *Macrosiphum* sp. *A;* used as a fumigant, it was efficient against *Macrosiphum* sp. *C* (Table 3) and the one species of lady-beetle tested; used as an infusion (No. 501c), it was efficient against *Aphis rumicis* and *Macrosiphum solanifolii;* used as a decoction (No. 501a), it was efficient but slow against *Aphis* spp. *A* and *B;* and used as a hot-water extract (No. 501b), it was efficient against the same species. Used as a cold-water extract (No. 528, Table 7) with soap, it had practically no effect on *Macrosiphum solanifolii*, *M.* sp. *C*, and *Aphis* sp. *E*.

The cold alcoholic extract (No. 506) of "cube," used without soap, was efficient against silkworms and *Macrosiphum* sp. *A* (Table 5); used with soap it was efficient against *Aphis* spp. *A*, *B*, and *E* (Tables 4, 6, and 7), *Macrosiphum* sp. *A* (Tables 5 to 7), *M. rosae*, *M. solanifolii*, *M.* sp. *C*, *Aphis spiraecola* (Table 6), *M. liriodendri*, and against potato-beetle larvæ and sawfly larvæ, but inefficient against webworms and the adults of potato beetles; and used with kerosene emulsion, it was efficient against *Macrosiphum solanifolii*, *M.* sp. *C*, and *Aphis* spp. *C*, *D*, and *E* (Table 6). The hot-water extract (No. 525), used with soap, was efficient against *Macrosiphum* sp. *A*, but inefficient against *Aphis* sp. *E* (Table 7). The benzene extract, used with soap, was efficient against *Macrosiphum* sp. *A* (Table 5), and *M. rosae.* The dry resin (No. 526) from the powder, dissolved in alcohol and used with soap, was inefficient against *Macrosiphum solanifolii*, *M.* sp. *C*, *Aphis spiraecola*, and *A.* sp. *E* (Table 7). The filtrate (No. 527), obtained from a cold alcoholic extract which had been concentrated, precipitated in water, and filtered, was practically ineffective against *Macrosiphum solanifolii*, *M.* sp. *C*, and *Aphis* sp. *E* (Table 7).

The powder of "cube," dusted into the hair of three cats badly infested with Mallophaga, was efficient, but the cats became sick from licking themselves.

DERRIS.

Following are the summarized results, obtained by using a commercial powder, consisting of a mixture of *Derris elliptica* and *D. uliginosa.* The powder, used as a dust (No. 110, Table 2), was efficient against three species of aphids (*Aphis* sp. *A* and *B*, and *Macrosiphonella sanborni*), and silkworms (Table 1), but killed only about half of the *Macrosiphum* sp. *A* tested within 24 hours; used as a decoction (No. 110a, not filtered) and also as a hot-water extract (No. 110b, filtered), it was efficient against *Aphis* sp. *A* and *B* (Table 3), and used as a fumigant (No. 110) it was efficient

against *Myzus persicae*, *Macrosiphum* sp. *C*, silkworms, and the lady-beetle tested, but inefficient against webworms and small tent caterpillars.

The alcoholic and benzene extracts of derris, when sufficiently strong and used with soap or kerosene emulsion, were found efficient against many species of aphids (Tables 4 to 6). The alcoholic extract, used with soap, was efficient against half-grown sawfly larvæ, but inefficient against small webworms (first instar) and the larvæ and adults of potato beetles.

At Tallulah, La., a commercial preparation of powdered derris was used on three dogs which were infested with fleas (*Ctenocephalus canis* Curt.). It was found efficient against the fleas.

SANDBOXTREE.

None of the six preparations of the sandboxtree (*Hura crepitans*) sprayed on aphids proved efficient (Table 8). A 10 per cent and a 20 per cent sap killed most of the aphids tested within three days, but this reaction time is entirely too slow for practical purposes, and even the sap 5 per cent and 10 per cent mixed with soap was inefficient. The alcoholic extracts of the bark and sawdust were inefficient, but the extract of the bark seems promising, and probably a stronger mixture would have been efficient.

TOMATO VINES.

Powders from tomato vines (*Lycopersicum esculentum*), applied as dusts, were ineffective on webworms, silkworms, potato-beetle larvæ, rose aphids, and tent caterpillars, but they had a considerable effect on roaches; mixed with food, they had a slight effect on grasshoppers and roaches and seemed efficient against flies (No. 11, Table 1). Used as a fumigant, the powder was practically ineffective against *Myzus persicae*.

The water extracts from tomato vines had practically no effect on bees and tent caterpillars, but affected grasshoppers and flies considerably. The alcoholic and ether extracts were very effective on flies and bees.

CHINABERRY.

The hot-water extract of the berries of the chinaberry (*Melia azedarach*) and also of the undried berries was efficient against bees and had a slight effect on roaches. The powdered leaves and water extracts (not filtered) from this powder were efficient against silkworms, but had only a slight effect on *Aphis* spp. *A* and *B* (Nos. 23k and 301a, Tables 2 and 3), and on tent caterpillars.

The alcoholic, ether, and petroleum-ether extracts of chinaberry were fatal to bees; but a strong alcoholic extract did not kill any of the silkworms tested. The alcoholic and benzene extracts (Nos. 505 and 514, Table 4), used with soap were inefficient against *Aphis* spp. *A* and *B*, *Macrosiphum* sp. *A*, and *M. liriodendri*.

TOBACCO.

The results obtained by using common tobacco (*Nicotiana tabacum*) in the form of nicotine resinate and sulphate are as follows: About 90 per cent of the chrysanthemum aphids and 98 per cent of the nas-

turtium aphids sprayed with nicotine resinate were killed, while the same mixture applied to apple trees was efficient against *Aphis pomi.* The results obtained with nicotine sulphate are given in Tables 4 to 6.

CASTOR-BEAN.

The juice from the leaves and green pods of a castor-bean plant (*Ricinus communis*) had only a slight effect on bees. The powdered beans and husks, free of oil, killed all the bees tested; but some of this powder, after having been extracted with a 10 per cent solution of sodium chlorid, apparently did not kill any of the bees tested. Several attempts at feeding dough mixed with the powdered beans to roaches failed. The powder had no effect on webworms, but had a slight effect on silkworms, flies, and grasshoppers.

An alcoholic extract of castor-beans, when reasonably strong and used with soap (No. 511, Table 4), was inefficient against three species of aphids (*Aphis* spp. *A* and *B*, and *Macrosiphum* sp. *A*), but when fed to silkworms without the addition of soap it had no effect on these larvæ. A benzene extract (No. 520), when exceedingly strong and used with soap, was efficient against *Macrosiphum* sp. *A*, but the control mixture seemed to have killed half the number.

SABADILLA.

Using sabadilla seed (*Schoenocaulon officinale*), the following results were obtained: The powders (Nos. 56 and 121, *oil extracted*), used as dusts, were efficient against grasshoppers, roaches, bees (Table 1), silkworms, and webworms, but they had practically no effect on five species of aphids (*Aphis rumicis*, *A. brassicae*, *A.* spp. *A* and *B*, and *Macrosiphonella sanborni*); the powder (No. 113, *oil not extracted*), used also as a dust, was efficient against silkworms (Table 1), but had practically no effect on the third, fourth (Table 2), and fifth species of the above aphids.

The powders (Nos. 56 and 113) of sabadilla seed, used as fumigants, had only a slight effect on silkworms and webworms, but were efficient against *Macrosiphum* sp. *C* and *Myzus persicae* (Table 3) and against the one lady-beetle tested.

The powder (No. 56a) of sabadilla seed, used as a decoction, had no effect on *Aphis* spp. *A* and *B* (Table 3). A soda extract, used as a spray material, had no effect on nasturtium and cabbage aphids, but was efficient against grasshoppers, bees, and small webworms. Hot and cold water extracts, used as spray materials, had no effect on nasturtium and cabbage aphids, but were efficient against grasshoppers, bees, and silkworms. An oil, extracted by petroleum ether and used as a spray material, suspended in water, was efficient against grasshoppers. Oxalic acid extracts were efficient against silkworms, while oxalic acid, used as a control, had no effect on them. A distillate also had no effect on silkworms. The alcoholic and benzene extracts (Nos. 510 and 519), used with soap (Table 4), were inefficient against three species of aphids (*Aphis* spp. *A* and *B* and *Macrosiphum* sp. *A*). The alcoholic extract was efficient but very slow against silkworms.

HELLEBORE.

The commercial powder of white false-hellebore (*Veratrum album*), used as a dust, was efficient but slow against roaches and silkworms,

and had a slight effect on bees (No. 109, Table 1) and tent caterpillars, and on *Aphis* spp. *A* and *B* (No. 502, Table 2); used as a decoction (No. 502a, not filtered), it had no effect on the same species of aphids (Table 3); used as a fumigant (No. 502), it killed only 75 per cent of the *Macrosiphum* sp. *C* tested, besides the one lady-beetle and one of the five large webworms tested; and used as a stomach poison, it was efficient but slow against grasshoppers and silkworms (No. 109, Table 1).

The hot and cold water extracts, alcoholic extract, and distillate from white hellebore were efficient but slow against silkworms, although a 0.5 per cent solution of veratrine in weak sulphuric acid killed the silkworms more quickly. The alcoholic and benzene extracts, used with soap (Nos. 508 and 517, Table 4), were inefficient against four species of aphids (*Aphis* spp. *A* and *B*, *Macrosiphum* sp. *A*, and *M. liriodendri*).

The powdered roots of white hellebore and the hot-water extract of these (not commercial) were found efficient but very slow against silkworms, although they had no effect on rose aphids.

COMPARATIVE RESULTS DISCUSSED.

Powders dusted upon or fed to six species of insects.—Reference to Table 1 shows the following: Of the five powders dusted upon roaches, sabadilla and pyrethrum kill quickly and seem almost equally efficient; derris has no practical value; and since hellebore and amianthium, although efficient, kill so slowly, they can not be recommended as satisfactory roach poisons.

Relative to the four powders fed to and dusted upon grasshoppers, all were efficient, but only pyrethrum killed quickly, and for practical purposes none of these can replace the arsenicals as grasshopper poisons.

Of the five powders fed to and dusted upon silkworms, only derris, amianthium, and pyrethrum killed quickly, although hellebore and sabadilla were efficient but slow.

Relative to the four powders used against flies, pyrethrum seems to be the best dust, but derris is a close second. Used as a stomach poison, amianthium killed all the flies tested within four or five days; and amianthium used as a dust killed all of them within four days.

Of the three powders dusted upon honeybees, sabadilla and amianthium killed them comparatively quickly, while hellebore acted slowly.

Of the three powders dusted upon potato-beetle larvæ in a potato patch, pyrethrum acted the most quickly, although all the larvæ dusted with derris, "cube," and pyrethrum were dead within 24 hours.

Powders dusted upon aphids.—Reference to Table 2 shows the following: Used as dusts, sabadilla, amianthium, and hellebore had no practical value against two species of aphids (*Aphis* sp. *A* omitted for these powders). Pyrethrum was efficient against all five species of aphids tested; while "cube" was efficient against four out of five species, and derris against three out of four species tested.

Powders used as fumigants, decoctions, infusions, and hot-water extracts.—Reference to Table 3 shows the following: Used as fumi-

gants against two species of aphids, sabadilla, pyrethrum, derris, and "cube" were efficient, while hellebore was inefficient.

Used as decoctions against *Aphis* spp. *A* and *B*, sabadilla, amianthium, and hellebore had practically no effect (*Aphis* sp. *A* omitted for these three powders); but pyrethrum, derris, and "cube" were efficient. Used as hot-water extracts (decoctions filtered) against the same species, pyrethrum had no effect; derris killed 60 per cent within 24 hours, while "cube" killed practically all within the same time.

Used as an infusion against two other species of aphids, "cube" was quickly efficient.

Alcoholic and benzene extracts of various powders.—Reference to Table 4 shows the following:[8] The alcoholic extracts+soap+water (2+4+100) of sabadilla, amianthium, and hellebore were inefficient against *Aphis* spp. *A* and *B*, while those of pyrethrum, derris, and "cube" were efficient. The alcoholic extracts (8+2+100) of the first three powders were also inefficient against *Macrosiphum* sp. *A*, while the benzene extracts (8+2+100) of the same powders seemed efficient, although the control mixture evidently killed 50 per cent of them. The nicotine sulphate (1/1,200)+soap+water (0.8+2+100) was efficient, although it killed rather slowly.

Alcoholic and benzene extracts and nicotine sulphate against Macrosiphum sp. A.—Reference to Table 5 shows the following comparative results obtained by spraying *Macrosiphum* sp. *A*: The alcoholic extracts+water (4+100) of "cube," derris, and pyrethrum were efficient within three days; "cube" is best and derris is slightly better than pyrethrum.

The alcoholic extracts+soap+water (4+2+100) of "cube," derris, and pyrethrum and nicotine sulphate (1/400)+soap+water (2.5+2+100) are about equally toxic; the same extracts (2+2+100) and nicotine sulphate (2.5+2+100) are about equally toxic, but the extract of pyrethrum acts the most slowly; the alcoholic and benzene extracts (1+2+100) of "cube" and derris and nicotine sulphate (2.5+2+100) are equally efficient, but the alcoholic and benzene extracts (1+2+100) of pyrethrum are inefficient; the alcoholic extract (3/4+2+100) and the alcoholic and benzene extracts (1/2+2+100) of "cube," and nicotine sulphate (2.5+2+100) are about equally toxic, while those of derris are less toxic and may be compared with nicotine sulphate (1/800) or (1.25+2+100), and those of pyrethrum are far below efficiency; the alcoholic and benzene extracts (1/3, 1/4, 1/5, and 1/6+2+100) of "cube" and nicotine sulphate (1.25+2+100) compare favorably in toxicity, while those (1/3 and 1/4+2+100) of derris are inefficient.

Alcoholic extracts and nicotine sulphate against 11 species of aphids.—Reference to Table 6 shows the comparative results obtained by spraying 11 species of aphids with alcoholic extracts. In

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[8] In Tables 4 to 8 the expression "alcoholic extract + soap + water (2 + 4 + 100)" means that the extract from 2 pounds of powder was mixed with 4 pounds of fish-oil soap and 100 gallons of water. The expression "Control, alcohol + soap + water (2 + 4 + 100)" means the same amount of alcohol, soap, and water as used in the preceding mixture; or, in other words, this mixture differs from the preceding only in that it does not contain the dry extract. The expression "40 per cent nicotine sulphate (1/1,200) + soap + water (0.8 + 2 + 100)" means 1 part by volume or 0.8 pound of nicotine sulphate to 1,200 parts of soap solution (2 pounds to 100 gallons of water). The weight of the nicotine sulphate is merely given so that its cost can be compared with that of the various powders used.

this table the results obtained by spraying the extracts of "cube," derris, and pyrethrum, and the nicotine sulphate upon *Macrosiphum* sp. *A* are the same as recorded in Table 5.

The extracts+soap+water (2, 1, and 1/2+2+100) of "cube," those of derris (2 and 1+2+100), and nicotine sulphate (1/400)+soap+water (2.5+2+100) are equally toxic against *Macrosiphum rosae* (none over half grown); while pyrethrum extract (2+2+100), derris extract (1/2+2+100), and nicotine sulphate (1/800) are about equally toxic, but the pyrethrum extracts (1 and 1/2+2+100) were less toxic and were inefficient.

The potato aphis (*M. solanifolii*), living on the pubescent underside of the leaves of a western jimson weed (*Datura meteloides* Dunal), were particularly difficult to kill. Nicotine sulphate (1/400) with soap (2+100) killed only 75 per cent of them within 24 hours, and nicotine sulphate (1/800) only 60 per cent; but when the soap was doubled, 95 per cent of the aphids were killed by each of the nicotine sulphate solutions. The extracts+soap+water (4+4+100) of "cube," derris, and pyrethrum were found efficient against this aphis, but a "cube" extract (2+2+100) killed only 50 per cent of them within 24 hours. The most satisfactory mixtures tested on this aphis were kerosene emulsions containing the extracts. The extracts+water (1+100) of "cube," derris, and pyrethrum+2.5 per cent of kerosene emulsion were about equally toxic and efficient; while the pyrethrum extract (2+100), derris extract (1+100), and "cube" extracts (1 and 1/2+100), each +1.25 per cent kerosene emulsion, were efficient; but the pyrethrum extract (1 and 1/2+100), and derris extract (1/2+100), each +1.25 per cent of kerosene emulsion, were inefficient. The extracts + soap + water (1+4+100) killed about 20 per cent of the aphids, while the control mixture containing 2.5 per cent of kerosene emulsion killed only 15 per cent of the aphids sprayed. This shows the effect of adding the extracts to the kerosene emulsion.

Table 6 shows that these alcoholic extracts are very promising insecticides, although not all of the 11 species of aphids tested were easily killed by them. Regarding the minimum dosage required to produce efficient killing, which is here considered 90 per cent or more within 24 hours, it appears that "cube" extract is 12 times as toxic as pyrethrum extract and 3 times as toxic as derris extract. These differences in toxicity are partially explained by the fact that the concentration of the "cube" extract is 5.29 per cent, while the concentrations of the derris and pyrethrum extracts, respectively, are 2.89 per cent and 4.08 per cent. Relative to the following four insecticides used with soap (2 pounds to 100 gallons of water), the lowest concentrations found which produce efficient killing are: Pyrethrum extract from 2 pounds of powder, derris extract from one-half pound, "cube" extract from one-sixth pound, and 40 per cent nicotine sulphate (1/1,200 strength).

Various extracts from "cube" against aphids.—Reference to Table 7 shows the comparative results obtained by spraying five species of aphids with various "cube" extracts. Practically no difference in toxicity between the cold and hot alcoholic extracts is shown. The resin was inefficient in all tests, and consequently contains only a portion of the toxic principle present in this plant, but in the

studies on derris (*61*) the resin was found to be the toxic principle. The filtrate and cold-water extract were practically ineffective. (See p. 7.)

Extracts of "cube," derris, and pyrethrum, and nicotine sulphate used in field experiments.—Four rows of potatoes, badly infested with potato beetles, and one large rose bush, badly infested with rose aphids, were sprayed with a commercial extract of derris (1/400) in soap solution (4/100). Another four rows of potatoes and another rose bush, similarly infested, were sprayed with a commercial soapy extract of pyrethrum (1/400) in soap solution (4/100), fish-oil soap being used in all these tests. Both preparations were found efficient against the potato-beetle larvæ, but had practically no effect on the adult potato beetles and were inefficient against the rose aphids.

In July and August, 1922, the following experiments were performed on aphids at Tallulah, La., by mixing various dilutions of the insecticides with soap solution (4/100), laundry soap being used. Small portions of rows of cotton plants, each 100 feet long and badly infested with the cotton aphis (*Aphis gossypii* Glover), were sprayed with alcoholic extracts of "cube," derris, and pyrethrum (prepared in the laboratory), with commercial extracts of derris and pyrethrum, and with 40 per cent nicotine sulphate.

Using the laboratory products, the following percentages of aphids were killed:

	Per cent.
"Cube:"	
1/2+4+100	99
1/3+4+100	98
1/4+4+100	95
Derris:	
1/3+4+100	95
Pyrethrum:	
1+4+100	90

Using the commercial products, the following percentages of aphids were killed:

	Per cent.
Derris:	
1/2,000	95
1/1,600	99
1/1,000	99
40 per cent nicotine sulphate:	
1/1,600	95
1/1,200	96
1/800	99
Pyrethrum:	
1/1,000	95

The following percentages were obtained by spraying many large weeds heavily infested with large red aphids (*Macrosiphum ambrosiae* Thos.), with some of the preceding products:

	Per cent.
Derris:	
1/1,600	100
40 per cent nicotine sulphate:	
1/1,200	100
Pyrethrum:	
1/1,000	95
"Cube:"	
1/3+4+100	100

TABLE 1.—*Comparative results obtained by testing various powders against six species of insects in the form of dusts and stomach poisons.*

Sample No.	Species and preparation.	Number of insects and how tested.			Percentage of insects dead within—[1]							
		Number of individuals.	Number of sets.	How tested.	6 hours.	1 day.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.
	Roaches:											
33a	Amianthium[2]	120	6	Dusted	0	5	50	61	89	97	99	100
33b	Do[3]	120	6	...do...	1	8	13	79	90	98	99	100
109	Hellebore	120	6	...do...	0	7	13	36	54	78	84	91
110	Derris	25	1	...do...	8	44	76	88	88	88	88	88
56	Sabadilla[4]	25	1	...do...	24	32	84	100	......	......	......	......
103	Pyrethrum	25	1	...do...	20	72	100	......	......	......	......	......
501	"Cube"	25	1	...do...	4	76	92	96	96	96	96	96
	Control	120	6	....	0	4	5	7	9	12	21	35
	Grasshoppers:											
33a	Amianthium	30	2	Fed	0	7	13	23	57	90	100	......
33b	Do	20	2	...do...	0	10	30	50	80	85	100	......
35f	Do[2]	33	2	Dusted	3	27	54	100	......	......	......	......
109	Hellebore	10	1	Fed	0	10	20	30	50	90	100	......
56	Sabadilla	36	3	Dusted	28	75	92	97	100	......	......	......
103	Pyrethrum	10	1	...do...	10	100	......	......	......	......	......	......
	Control	20	2	....	0	0	0	0	0	30	55	......
	Silkworms:											
121	Sabadilla[5]	70	7	Dusted	11	24	57	76	87	93	97	100
113	Do[6]	90	9	...do...	24	57	63	97	99	100	......	......
109	Hellebore	40	4	...do...	5	28	48	65	75	86	93	100
109	Do	20	2	Fed	0	15	40	85	85	95	100	......
103	Pyrethrum	50	5	Dusted	48	88	96	100	......	......	......	......
33a	Amianthium	20	2	Fed	15	60	100	......	......	......	......	......
33b	Do	20	2	...do...	10	100	......	......	......	......	......	......
110	Derris	40	4	Dusted	100	......	......	......	......	......	......	......
	Control	90	9	....	0	0	0	0	0	0	0	0
	Flies:											
33a	Amianthium	10	1	Dusted	0	20	60	80	100	......	......	......
33b	Do	10	1	...do...	0	10	50	70	100	......	......	......
33a	Do	10	1	Fed	0	40	60	70	100	......	......	......
33b	Do	10	1	...do...	0	20	30	40	90	100	......	......
11	Tomato[7]	100	5	...do...	0	12	52	60	96	100	......	......
110	Derris[8]	([9])	......	Dusted	......	100	......	......	......	......	......	......
103	Pyrethrum	6	1	...do...	100	......	......	......	......	......	......	......
	Control	100	5	....	0	5	28	28	33	......	......	......
	Honeybees:											
109	Hellebore	40	2	Dusted	3	68	68	......	......	......	......	......
35f	Amianthium	20	1	...do...	15	50	100	......	......	......	......	......
56	Sabadilla	40	2	...do...	50	100	......	......	......	......	......	......
	Control	40	2	....	0	0	0	......	......	......	......	......
	Potato-beetle larvæ:											
110	Derris	100	1	Dusted	25	100	......	......	......	......	......	......
501	"Cube"	100	1	...do...	25	100	......	......	......	......	......	......
103	Pyrethrum	100	1	...do...	50	100	......	......	......	......	......	......
	Control	100	1	....	0	0	......	......	......	......	......	......

[1] Where a test did not continue for 7 days, columns are left blank.
[2] No. 200 powder from bulbs.
[3] No. 200 powder from leaves.
[4] No. 100 powder, oil extracted.
[5] No. 40 powder, oil extracted.
[6] No. 40 powder, oil not extracted.
[7] No. 60 powder from vines.
[8] From derris paper (*61*).
[9] Many.

TABLE 2.—*Comparative results obtained by dusting aphids with various powders.*

Sample No.	Species and preparation.	Estimated number of individuals.	Number of sets.	Percentage of aphids dead within—[1]				
				6 hours.	1 day.	2 days.	3 days.	4 days.
	Aphis sp. B:							
56	Sabadilla[2]	100	1	0	5	10	40	....
113	Do[3]	100	1	0	5	10	40	....
23k	Chinaberry[4]	100	1	0	10	25	50	....
33a	Amianthium[5]	100	1	....	....	15	25	....
33b	Do[4]	100	1	....	....	5	50	....
35e	Do[4]	100	1	....	....	25	50	....
35f	Do[5]	100	1	....	....	75	80	....
502	Hellebore	100	1	....	....	10	40	....
103	Pyrethrum	100	1	95	100	....	....	....
110	Derris	100	1	25	....	100	....	....
501	"Cube"	100	1	15	....	100	....	....

[1] Where a test did not continue for 4 days columns are left blank.
[2] Oil extracted.
[3] Oil not extracted.
[4] No. 200 powder of leaves.
[5] No. 200 powder of bulbs.

TABLE 2.—*Comparative results obtained by dusting aphids with various powders*—Continued.

Sample No.	Species and preparation.	Estimated number of individuals.	Number of sets.	Percentage of aphids dead within— 6 hours.	1 day.	2 days.	3 days	4 days.
	Aphis sp. A:							
103	Pyrethrum	100	1	95	100	...	...	...
110	Derris	100	1	25	...	100	...	...
501	"Cube"	100	1	10	...	100	...	...
	Macrosiphum sp. A:							
521	Hura crepitans [1]	500	1	20	20	80	...	...
522	Do [2]	500	1	20	30	80	...	...
503	Pyrethrum	1,500	3	86	88	98	100	...
110	Derris	1,000	2	20	50	75	85	92
501	"Cube"	1,500	3	20	43	70	83	97
	Macrosiphum sp. B:							
503	Pyrethrum	100	1	99	100	...	...	...
	Macrosiphum solanifolii:							
501	"Cube"	300	1	...	99	100	...	...
	Aphis rumicis:							
501	"Cube"	200	1	50	98	100	...	...
	Macrosiphonella sanborni:							
103	Pyrethrum	1,000	2	99	100	...	...	...
110	Derris	500	1	...	...	...	...	100

[1] No. 200 powder of bark. [2] No. 200 powder of sawdust.

TABLE 3.—*Comparative results obtained by testing various powders against aphids in the form of fumigants, decoctions, infusions, and hot-water extracts.*

Sample No.	Preparation and how used.	Insects tested. Estimated number of individuals.	Number of sets.	Species.	Percentage of aphids dead within— [1] 6 hours.	1 day.	2 days.	3 days.
	Fumigant:							
56	Sabadilla burned	100	1	Macrosiphum sp. C	95	98	...	...
502	Hellebore burned	100	1	do	...	75	...	...
103	Pyrethrum burned	100	1	do	100	100	...	...
110	Derris burned	100	1	do	...	100	...	...
501	"Cube" burned	100	1	do	...	100	...	...
113	Sabadilla burned	100	1	Myzus persicae	98	100	...	...
103	Pyrethrum burned	100	1	do	100	100	...	...
110	Derris burned	100	1	do	...	95	...	...
	Decoction not filtered:							
56a	Sabadilla sprayed	100	1	Aphis sp. B	0	0	5	10
301a	Chinaberry sprayed.	100	1	do	0	0	0	5
35fa	Amianthium sprayed	100	1	do	0	5	10	25
502a	Hellebore sprayed	100	1	do	0	0	0	5
103a	Pyrethrum sprayed.	100	1	do	50	85	95	100
110a	Derris sprayed	100	1	do	0	50	90	99
501a	"Cube" sprayed	100	1	do	0	50	80	90
103a	Pyrethrum sprayed.	100	1	Aphis sp. A	50	95	99	100
110a	Derris sprayed	100	1	do	0	50	90	99
501a	"Cube" sprayed	100	1	do	0	40	50	95
	Water extract (decoction filtered):							
103b	Pyrethrum sprayed.	100	1	do	0	0	...	...
103b	Do	100	1	Aphis sp. B	0	2	...	...
110b	Derris sprayed	100	1	do	5	60	...	...
110b	Do	100	1	Aphis sp. A	5	60	...	...
501b	"Cube" sprayed	100	1	do	10	95	...	...
501b	Do	100	1	Aphis sp. B	5	98	...	...
	Infusion not filtered:							
501c	"Cube" sprayed	200	1	Aphis rumicis	...	98	...	...
501c	Do	600	1	Macrosiphum solanifolii.	...	99	...	...

[1] Where a test did not continue for 3 days, columns are left blank.

TABLE 4.—*Comparative results obtained by spraying aphids with the alcoholic and benzene extracts derived from various powders.*

Sample No.	Preparation.	Insects tested.			Percentage of aphids dead within—[1]			
		Estimated number of individuals.	Number of sets.	Species.	6 hours.	1 day.	2 days.	3 days.
	Alcoholic extract+soap+water (2+4+100):							
510	Sabadilla	100	1	Aphis sp. A		20	40	
510	Do	100	1	Aphis sp. B		30	60	
505	Chinaberry	100	1	Aphis sp. A		30	90	
505	Do	100	1	Aphis sp. B		40	95	
504	Amianthium	100	1	Aphis sp. A		40	75	
504	Do	100	1	Aphis sp. B		60	75	
511	Castor bean	100	1	Aphis sp. A		30	50	
511	Do	100	1	Aphis sp. B		20	40	
508	Hellebore	100	1	Aphis sp. A		30	75	
508	Do	100	1	Aphis sp. B		40	70	
509	Pyrethrum	100	1	Aphis sp. A		95	100	
509	Do	100	1	Aphis sp. B		95	100	
507	Derris	100	1	Aphis sp. A		95	100	
507	Do	100	1	Aphis sp. B		95	99	100
506	"Cube"	100	1	Aphis sp. A		95	100	
506	Do	100	1	Aphis sp. B		100		
	Control, alcohol+soap+water (2+4+100)	100	1	Aphis sp. A		10	25	
	Do	100	1	Aphis sp. B		10	15	
	Alcoholic extract+soap+water (8+2+100):							
510	Sabadilla	500	1	Macrosiphum sp. A	10	50	55	55
505	Chinaberry	500	1	do	5	10	20	25
504	Amianthium	500	1	do	5	10	20	30
511	Castor bean	500	1	do	30	50	60	75
508	Hellebore	500	1	do	50	75	80	85
	Control, alcohol+soap+water (4+2+100)	500	1	do	5	15	15	15
	Benzene extract+soap+water (8+2+100):							
519	Sabadilla	500	1	do	50	85	90	
514	Chinaberry	500	1	do	60	85	85	
513	Amianthium	500	1	do	50	75	85	
520	Castor bean	500	1	do	70	95	99	
517	Hellebore	500	1	do	60	85	90	
	Control, benzene+soap+water (8+2+100)	500	1	do	50	50	50	
	40 per cent nicotine sulphate (1/1200)+soap+water (0.8+2+100)	1,500	3	do	91	95	97	100

[1] Where a test did not continue for 3 days, columns are left blank.

TABLE 5.—*Comparative results obtained by spraying Macrosiphum sp. A with alcoholic and benzene extracts derived from "cube," derris, and pyrethrum, and with 40 per cent nicotine sulphate.*

Preparation.	Aphids sprayed with alcoholic extracts.						Aphids sprayed with benzene extracts.					
	Number of sets.	Estimated number of individuals.	Percentage of aphids dead within—[1]				Percentage of aphids dead within—[1]				Number of sets.	Estimated number of individuals.
			6 hours.	1 day.	2 days.	3 days.	6 hours.	1 day.	2 days.	3 days.		
Extract+water (4+100):												
"Cube"	1	500	50	95	100	......	......	......	......	......	......	......
Derris	1	500	50	85	90	95	......	......	......	......	......	......
Pyrethrum	1	500	60	80	85	90	......	......	......	......	......	......
Extract+soap+water (4+2+100):												
"Cube"	3	1,680	99	100	......	......	......	......	......	......	......	......
Derris	3	1,500	98	100	......	......	......	......	......	......	......	......
Pyrethrum	3	1,700	97	98	100	......	......	......	......	......	......	......
Extract+soap+water (2+2+100):												
Pyrethrum	1	500	90	95	100	......	......	......	......	......	......	......
Derris	1	500	100	......	......	......	......	......	......	......	......	......
"Cube"	1	500	99	100	......	......	......	......	......	......	......	......
Extract+soap+water (1+2+100):												
"Cube"	5	2,500	100	......	......	......	98	98	100	......	1	500
Derris	4	2,000	99	100	......	......	98	98	100	......	1	500
Pyrethrum	4	2,000	62	76	80	......	60	85	85	......	1	500
Extract+soap+water (3/4+2+100):												
Pyrethrum	1	500	30	60	70	......	......	......	......	......	......	......
Derris	1	500	93	98	100	......	......	......	......	......	......	......
"Cube"	1	500	100	......	......	......	......	......	......	......	......	......
Extract+soap+water (1/2+2+100):												
"Cube"	6	3,000	98	100	......	......	98	98	100	......	2	1,000
Derris	5	2,500	93	97	100	......	95	97	99	......	2	1,000
Pyrethrum	1	500	25	40	50	......	50	60	85	......	1	500
Extract+soap+water (1/3+2+100):												
Derris	4	2,000	77	82	89	95	50	85	92	......	1	500
"Cube"	5	2,500	95	99	100	......	90	96	97	......	1	500
Extract+soap+water (1/4+2+100):												
"Cube"	5	2,500	96	99	100	......	90	90	93	......	1	500
Derris	2	1,000	60	62	70	80	50	60	60	......	1	500
Extract+soap+water (1/5+2+100) "cube"	2	1,000	93	97	99	100	......	......	......	......	......	......
Extract+soap+water (1/6+2+100) "cube"	3	1,500	93	97	99	100	......	......	......	......	......	......
40 per cent nicotine sulphate (1/400)+soap+water (2.5+2+100)	6	3,000	98	99	100	......	......	......	......	......	......	......
40 per cent nicotine sulphate (1/800)+soap+water (1.25+2+100)	6	3,000	95	98	100	......	......	......	......	......	......	......
40 per cent nicotine sulphate (1/1,200)+soap+water (0.8+2+100)	3	1,500	91	95	97	100	......	......	......	......	......	......

[1] Where a test did not continue for 3 days, columns are left blank.

TABLE 5.—*Comparative results obtained by spraying Macrosiphum sp. A with alcoholic and benzene extracts derived from "cube," derris, etc.*—Continued.

Preparation.	Aphids sprayed with alcoholic extracts.						Aphids sprayed with benzene extracts.					
	Number of sets.	Estimated number of individuals.	Percentage of aphids dead within—				Percentage of aphids dead within—				Number of sets.	Estimated number of individuals.
			6 hours.	1 day.	2 days.	3 days.	6 hours.	1 day.	2 days.	3 days.		
Control, solvent +soap+water (4+2+100)...	1	500	5	15	15	15	......	......	......	......	......	......
Control, solvent +soap+water (2+2+100)...	1	500	5	15	15	......	......	......	......	......	......	......
Control, solvent +soap+water (1+2+100)...	3	1,500	5	12	13	......	10	10	15	......	1	500
Control, solvent +soap+water (1/2+2+100)..	2	1,000	5	10	12	......	5	15	15	......	1	500

TABLE 6.—*Comparative results obtained by spraying 11 species of aphids with alcoholic extracts derived from "cube," derris, and pyrethrum, and with 40 per cent nicotine sulphate, mixed with soap solution and kerosene emulsion.*

Sample No.	Preparation.	Percentage of aphids dead within 24 hours.										
		Macrosiphum sp. A.	Macrosiphum rosae.	Macrosiphum solanifolii.	Macrosiphum sp. C.	Aphis sp. A.	Aphis sp. B.	Aphis sp. E.	Aphis spiraecola.	Macrosiphonella sanborni.	Aphis sp. C.	Aphis sp. D.
	Alcoholic extract+soap+water:											
509	8+4+100, Pyrethrum.	......	......	95	......	......	......	......	......	......	......	......
	4+4+100—											
509	Pyrethrum.......	......	......	90	......	......	......	......	......	......	......	......
507	Derris.........	......	......	98	......	......	......	......	......	......	......	......
506	"Cube".........	......	......	95	......	......	......	......	......	......	......	......
	4+2+100—											
509	Pyrethrum.......	98	......	......	......	......	......	......	......	......	......	......
507	Derris.........	100	......	......	......	......	......	......	......	......	......	......
506	"Cube".........	100	......	......	......	......	......	......	......	......	......	......
	2+4+100—											
506	"Cube".........	......	......	......	......	95	100	......	......	......	......	......
507	Derris.........	......	......	......	......	95	95	......	......	......	......	......
509	Pyrethrum.......	......	......	......	......	95	95	......	......	......	......	......
509	2+2+100—											
	Pyrethrum.......	95	92	......	......	......	......	......	......	......	......	......
507	Derris.........	100	100	......	......	......	......	......	......	......	......	......
506	"Cube".........	100	100	50	90	......	......	90	......	......	......	......
	1+2+100—											
506	"Cube".........	100	100	......	......	......	......	40	95	......	......	......
507	Derris.........	100	100	......	......	......	......	......	......	......	......	......
509	Pyrethrum.......	76	89	......	......	......	......	......	......	......	......	......
	3/4+2+100—											
509	Pyrethrum.......	60	......	......	......	......	......	......	......	......	......	......
507	Derris.........	98	......	......	......	......	......	......	......	......	......	......
506	"Cube".........	100	......	......	......	......	......	......	......	......	......	......
	1/2+2+100—											
506	"Cube".........	100	100	......	......	......	......	40	90	......	......	......
507	Derris.........	97	95	......	......	......	......	......	......	......	......	......
509	Pyrethrum.......	40	86	......	......	......	......	......	......	......	......	......
	1/3+2+100—											
507	Derris.........	82	......	......	......	......	......	......	......	......	......	......
506	"Cube".........	99	......	......	......	......	......	......	......	......	......	......
	1/4+2+100—											
506	"Cube".........	99	......	......	......	......	......	......	......	......	......	......
507	Derris.........	62	......	......	......	......	......	......	......	......	......	......
	1/5+2+100—											
506	"Cube".........	97	......	......	......	......	......	......	......	......	......	......
	1/6+2+100—											
506	"Cube".........	97	......	......	......	......	......	......	......	......	......	......

TABLE 6.—*Comparative results obtained by spraying 11 species of aphids with alcoholic extracts derived form "cube," derris, and pyrethrum, etc.*—Contd.

Sample No.	Preparation.	Percentage of aphids dead within 24 hours.										
		Macrosiphum sp. A.	Macrosiphum rosae.	Macrosiphum solanifolii.	Macrosiphum sp. C.	Aphis sp. A.	Aphis sp. B.	Aphis sp. E.	Aphis spiraecola.	Macrosiphonella sanborni.	Aphis sp. C.	Aphis sp. D.
	40 per cent nicotine sulphate:											
	1/400 + soap + water (2.5+2+100)	99	100	75	90	......	......	99	......	......	......	......
	1/800 + soap + water (1.25+2+100)	98	92	60	85	......	......	99	......	......	......	......
	1/1200 + soap + water (0.8+2+100)	95	......	......	......	......	......	......	......	......	......	......
	1/400 + soap + water (2.5+4+100)	......	......	95	......	......	......	......	......	100	......	......
	1/800 + soap + water (1.25+4+100)	......	......	95	......	......	......	......	......	......	......	......
	Control, alcohol+soap+water:											
	4+2+100	15	......	......	......	......	......	......	......	......	......	......
	2+2+100	15	......	0	5	......	......	10	20	......	......	......
	1+2+100	12	25	......	......	......	......	......	......	......	......	......
	1/2+2+100	10	......	......	......	......	......	......	......	......	......	......
	2+4+100	......	......	5	......	10	10	......	......	......	......	......
	Alcoholic extract+water (1+100)+10 per cent kerosene emulsion:											
506	"Cube"	......	......	100	......	......	......	......	......	......	......	......
507	Derris	......	......	100	......	......	......	......	......	......	......	......
	Alcoholic extract+water (2+100)+10 per cent kerosene emulsion:											
509	Pyrethrum	......	......	98	......	......	......	......	......	......	......	......
	Alcoholic extract+water (2+100)+5 per cent kerosene emulsion:											
509	Pyrethrum	......	......	99	......	......	......	......	......	......	......	......
	Alcoholic extract+water (1+100)+5 per cent kerosene emulsion:											
507	Derris	......	......	99	......	......	......	......	......	......	......	......
506	"Cube"	......	......	100	......	......	......	......	......	......	......	......
	Control, alcohol+water (2+100)+:											
	10 per cent kerosene emulsion	......	......	99	......	......	......	......	......	......	......	......
	5 per cent kerosene emulsion	......	......	65	......	......	......	......	......	......	......	......
	2.5 per cent kerosene emulsion	......	......	15	......	......	......	......	......	......	......	......
	Alcoholic extract+water (1+100)+2.5 per cent kerosene emulsion:											
506	"Cube"	......	......	99	98	......	......	92	......	......	98	98
507	Derris	......	......	98	100	......	......	88	......	......	90	97
	Alcoholic extract+water (2+100)+2.5 per cent kerosene emulsion:											
509	Pyrethrum	......	......	99	......	......	......	......	......	......	......	......
	Alcoholic extract+water (1+100)+2.5 per cent kerosene emulsion:											
509	Pyrethrum	......	......	95	65	......	......	70	......	......	60	95
	Alcoholic extract+water (2+100)+1.25 per cent kerosene emulsion:											
509	Pyrethrum	......	......	98	......	......	......	......	......	......	......	......
	Alcoholic extract+water (1+100)+1.25 per cent kerosene emulsion:											
509	Pyrethrum	......	......	75	......	......	......	......	......	......	......	......
507	Derris	......	......	98	......	......	......	......	......	......	......	......
506	"Cube"	......	......	99	......	......	......	......	......	......	......	......

TABLE 6.—*Comparative results obtained by spraying 11 species of aphids with alcoholic extracts derived form "cube," derris, and pyrethrum, etc.*—Contd.

Sample No.	Preparation.	Percentage of aphids dead within 24 hours.										
		Macrosiphum sp. A.	Macrosiphum rosae.	Macrosiphum solanifolii.	Macrosiphum sp. C.	Aphis sp. A.	Aphis sp. B.	Aphis sp. E.	Aphis spiraecola.	Macrosiphonella sanborni.	Aphis sp. C.	Aphis sp. D.
	Alcoholic extract+water (1/2+100)+1.25 per cent kerosene emulsion:											
506	"Cube"	......	......	90	......	......	......	......	......	......	......	......
507	Derris	......	......	80	......	......	......	......	......	......	......	......
509	Pyrethrum	......	......	50	......	......	......	......	......	......	......	......
	Alcoholic extract + soap+ water (1+4+100):											
509	Pyrethrum	......	......	15	......	......	......	......	......	......	......	......
507	Derris	......	......	20	......	......	......	......	......	......	......	......
506	"Cube"	......	......	20	......	......	......	......	......	......	......	......

TABLE 7.—*Comparative results obtained by spraying aphids with various extracts derived from "cube."*

Sample No.	Preparation.	Insects tested.			Percentage of aphids dead within —[1]			
		Estimated number of individuals.	Number of sets.	Species.	6 hours.	1 day.	2 days.	3 days.
	Alcoholic extract + soap+water:							
	2+2+100—							
506	Cold	500	1	Aphis sp. E	60	90	95	95
525	Hot	300	1	do	50	60	65	75
	1+2+100—							
525	Hot	300	1	do	30	40	50	60
506	Cold	300	1	do	30	40	50	60
506	Cold	2,500	5	Macrosiphum sp. A	100	......	......	......
525	Hot	500	1	do	100	......	......	......
	1/2+2+100—							
525	Hot	500	1	do	100	......	......	......
506	Cold	3,000	6	do	98	100	......	......
	1/3+2+100—							
506	Cold	2,500	5	do	95	99	100	......
525	Hot	500	1	do	100	......	......	......
	1/4+2+100—							
525	Hot	500	1	do	100	......	......	......
506	Cold	2,500	5	do	96	99	100	......
	1/6+2+100—							
506	Cold	1,500	3	do	97	99	100	......
525	Hot	500	1	do	95	100	......	......
	Resin dissolved in alcohol+soap+ water:							
526	2+2+100	800	2	Aphis sp. E	35	55	60	65
526	1+2+100	600	2	do	15	15	20	30
526	1/2+2+100	300	1	do	10	10	15	20
526	2+4+100	500	1	Macrosiphum solanifolii	......	75	......	......
526	2+2+100	500	1	do	30	40	40	......
526	2+2+100	100	1	Macrosiphum sp. C	60	60	......	......
526	1+2+100	300	1	Aphis spiraecola	40	50	60	......
526	1/2+2+100	300	1	do	40	40	50	......
	Filtrate from No. 506 +soap+water:							
527	2+4+100	500	1	Macrosiphum solanifolii	5	5	5	
527	2+2+100	500	1	do	5	5	5	......
527	2+2+100	100	1	Macrosiphum sp. C	10	10	......	......
527	2+2+100	500	1	Aphis sp. E	20	30	30	35
	Cold water extract+ soap+water:							
528	2+4+100	500	1	Macrosiphum solanifolii	5	5	5	......
528	2+2+100	500	1	do	5	5	5	......
528	2+2+100	100	1	Macrosiphum sp. C	10	10	......	......
528	2+2+100	500	1	Aphis sp. E	10	10	10	......

[1] Where a test did not continue for 3 days, columns are left blank.

TABLE 8.—*Effects of spraying aphids with the sap and alcoholic extracts of Hura crepitans.*

Sample No.	Preparation.	Insects tested.			Percentage of aphids dead within—[1]			
		Estimated number of individuals.	Number of sets.	Species.	6 hours.	1 day.	2 days.	3 days.
500	Sap 10 per cent	100	1	Aphis sp. A	0	40	60	95
500	Do	100	1	Aphis sp. B	0	60	70	99
512	Sap 20 per cent	500	1	Macrosiphum sp. A	5	50	60	95
500a	Sap + soap + water (5 per cent+4+100).	100	1	Aphis sp. A	....	30	60	....
500a	Do	100	1	Aphis sp. B	....	20	50	....
512a	Sap + soap + water (10 per cent+2+100).	2,000	4	Macrosiphum sp. A	29	70	84	92
	Control, soap+water (2+100).	500	1	.....do	5	10	15	15
	Control, soap+water (4+100).	100	4	Aphis sp. A	....	10	25	....
	Do	100	1	Aphis sp. B	....	10	15	....
523	Alcoholic extract of bark + soap + water (2+2+100).	1,000	2	Macrosiphum sp. A	30	55	92	....
524	Alcoholic extract of sawdust + soap + water (2+2+100).	1,000	2	.....do	20	30	50	....
	Control, alcohol + soap+water (2+2+100).	500	1	.....do	5	15	15	....
	40 per cent nicotine sulphate (1/1200)+soap+water (0.8+2+100).	1,500	3	.....do	91	95	97	100

[1] Where no test was taken, and where a test continued only 2 days, blanks are left.

DISCUSSION OF THE LESS IMPORTANT RESULTS OBTAINED.

A powder and decoction of the common yarrow (*Achillea millefolium*) had no effect on the aphids (*Macrosiphum* sp. *B*) tested.

The roots, leaves, and stems of Columbia monkshood (*Aconitum columbianum*), used as a stomach poison, had no effect on grasshoppers; and used as a dust, they had no effect on bees.

The leaves of a peach tree (*Amygdalus persica*), wet with the juice of mulberry-tree leaves, were fed to silkworms, and within 24 hours after eating this food practically all of the insects were dead.

A water extract of añiliton (see footnote on p. 26) had no effect on silkworms.

Cold and hot water extracts of sagebrush (*Artemisia tridentata*) had no effect on silkworms, webworms, potato-beetle larvæ, rose aphids, and nasturtium aphids, but these extracts slowly killed bees.

A water extract of añiliton (see footnote on p. 26) had no effect against small webworms and small catalpa caterpillars. Water and alcoholic extracts were efficient against bees. The powder, used as a fumigant, had no effect against small webworms; used as a dust, it had a slight effect on tent caterpillars and roaches; and used as a stomach poison, it had no effect on webworms and flies and only a slight effect on roaches and silkworms.

A water extract of balbec (see footnote on p. 26) killed silkworms quickly.

The juice, highly concentrated, from the green leaves and beans of catalpa (*Catalpa bignonioides*) had a slight effect on bees.

A water extract from the dried leaves and seeds of the American wormseed (*Chenopodium ambrosioides*) had no effect on bees. A strong decoction, mixed with soap, from the leaves, stems, and seeds had no effect on potato aphids and nasturtium aphids. The powder, used as a dust, had no effect on tent caterpillars, but a considerable effect on roaches; and used as a stomach poison, it had no effect on grasshoppers.

The powder and hot-water extract from the flower heads of the oxeye daisy (*Chrysanthemum leucanthemum*) had no effect on silkworms, webworms, potato-beetle larvæ, and rose aphids.

The powder from *Clibadium surinamense* had practically no effect on silkworms.

A hot-water extract of the stems of a fish-poison (*Cracca villosa purpurea*) had no effect on tent caterpillars.

Cold-water extracts from the tops of Scotch broom (*Cytisus scoparius*), collected in two different localities, had practically no effect on silkworms. Since this plant is reported to contain sparteine, a 0.5 per cent solution of sparteine sulphate was fed to silkworms. This solution proved efficient, but acted very slowly.

A water extract of jimsonweed (*Datura stramonium*) had no effect against small webworms and small catalpa caterpillars, and a highly concentrated water extract had only a slight effect on bees. The water extract, used as a fumigant, had no effect on small webworms. The powder, used as a stomach poison, had a slight effect on silkworms; and used as a dust, it had a slight effect on roaches and tent caterpillars.

Powders from the roots, leaves, and stems, and from the blossoms of low larkspur (*Delphinium bicolor*), and hot-water extracts from all of these powders had no effect on webworms, silkworms, grasshoppers, and potato-beetle larvæ, with one exception; the extract from the blossoms had a slight effect on silkworms.

A water extract from *Euphorbia cotinoides* had a considerable effect on silkworms.

A water extract from *Furcraea cubensis* had practically no effect on silkworms.

A powder and a decoction from galinsoga (*Galinsoga parviflora*) had no effect on the aphids (*Macrosiphum* sp. *B*) tested.

The juice from the green leaves of the Kentucky coffeetree (*Gymnocladus dioica*), mixed separately with sugar sirup, molasses, and honey, had no apparent effect on the many flies tested.

The powder from the heads of the bitterweed (*Helenium tenuifolium*) had only a very slight effect on silkworms, flies, and aphids (*Aphis* spp. *A* and *B*), but the decoction had no effect whatever on aphids of the same species.

A water extract from a Honduras fish-poison (see footnote on p. 26) was efficient against silkworms.

A powder from *Jatropha macrorhiza*, used as a dust, had a slight effect on tent caterpillars and roaches.

The powder from lambkill (*Kalmia angustifolia*), eaten by grasshoppers and dusted upon bees, had no effect.

The powder and a water extract from margarita (*Karwinskia humboldtiana*) were efficient but very slow against silkworms, although they had no effect on tulip-tree aphids. The powder had

a slight effect on catalpa caterpillars, while an alcoholic extract from it had no effect on small webworms and tulip-tree aphids.

A water extract of lancepod (*Lonchocarpus* sp.) had no effect on silkworms.

The powder from the common matrimony-vine (*Lycium halimifolium*), used as a dust, affected roaches considerably, but tent caterpillars only slightly; and used as a stomach poison, it had a considerable effect on grasshoppers. The water extract did not affect bees.

A commercial powder containing *Madhuca* sp. seeds was tested and found efficient but slow against silkworms, although within 48 hours it killed only about 35 per cent of the *Aphis* spp. *A* and *B* tested. A decoction of the powder had only a slight effect on the same species of aphids.

A water extract of the wood of moetoepoe (see footnote on p. 26) proved to be efficient, while a water extract of the leaves was found to be inefficient against silkworms.

A water extract of the leaves of necoetae (see footnote on p. 26) killed silkworms very slowly.

The powder from the leaves and stems of the common oleander (*Nerium oleander*) and a decoction from this powder had no effect on aphids (*Macrosiphum* sp. *B*).

An infusion and a decoction of the leaves of tree tobacco (*Nicotiana glauca*) with soap (1 pound to 50 gallons of water) had only a very slight effect on nasturtium aphids, while the powdered leaves had no apparent effect on them. (An analysis of some of the leaves, made by a chemist of a tobacco by-products company, showed that the nicotine content, upon a moisture-free basis, amounted to only 0.18 of 1 per cent).

The hot and cold water extracts of the bark and leaves of *Pangium edule* were found to be inefficient against tent caterpillars. The extracts from the bark appeared a little better than those from the leaves.

Neither the exhalation nor decoction from the green leaves of *Pongam pinnata* had any effect on nasturtium aphids.

A hot-water extract from the green tops of the American elder (*Sambucus canadensis*) had no effect on silkworms, webworms, or rose aphids.

A powder and a decoction from the whitetop-aster (*Sericocarpus asteroides*) had no effect on the aphids (*Macrosiphum* sp. *B*) tested.

The water extract of the horsenettle (*Solanum carolinense*) had no effect against small webworms and small catalpa caterpillars. The powder, used as a fumigant, had no effect against small catalpa caterpillars; used as a stomach poison, it had no effect against silkworms and webworms, but had a slight effect on grasshoppers; and used as a dust, it had a slight effect on tent caterpillars and roaches.

The powder from sleepy grass (*Stipa viridula*), used as a dust, had no effect on tent caterpillars, but had a slight effect on roaches.

A water extract of the bark of suma rubra (see footnote on p. 26) had a slight effect against silkworms.

A water extract of tssikoena (see footnote on p. 26) had a slight effect against silkworms.

The powdered roots of *Veratrum californicum* had no effect on grasshoppers.

The powder from the moth mullein (*Verbascum blattaria*), used as a dust, had a slight effect on roaches and tent caterpillars; used as a stomach poison, it had a very slight effect on grasshoppers and flies, but none at all on roaches, silkworms, and webworms. The water extract had no effect on webworms, potato-beetle larvæ, and rose aphids, but a slight effect on bees and silkworms. An alcoholic extract was fatal to bees.

The powders from the roots, stems, and leaves of zygadenus (*Zygadenus venenosus*) and hot-water extracts from these powders, had no effect on grasshoppers, webworms, and potato-beetle larvæ, and only a slight effect on silkworms.

CATALOGUE OF PLANTS TESTED FOR OR REPORTED TO POSSESS INSECTICIDAL PROPERTIES.

In 1919 Roark (*75*) catalogued and published the names of nearly 200 species of plants which had been tested for or reported to possess insecticidal properties. The present writers have been collecting the literature on this subject since 1915, but certainly would have overlooked some of the references had it not been for Roark's publication, which is not available for the average agricultural reader. The writers have verified, revised, and enlarged Roark's catalogue, and now it includes in all 267 species of plants, although 7 of these may be synonyms. The purpose of this catalogue is to serve as a handy reference and to encourage research along this line of work.

Relative to the best-known plant insecticides, only a few references are given, but in regard to the little-known ones all the references that could be found are included. To avoid duplications concerning the plants tested by the writers, the reader is merely referred to the pages on which the writer's results are given, and to facilitate finding all the information about any given species given in this bulletin, the reader is referred to the "Index of the botanical and common names of plants catalogued" on pages 59–61.

Achillea millefolium L. ASTERACEAE. **Common yarrow.** Europe, Asia, North America.

The writers' results are given on page 21.

Achillea nobilis L. **Camphor yarrow.** Europe.

Gieseler (*26*) reports that the flower heads have an action on insects similar to that of insect powder.

Aconitum columbianum Nutt. RANUNCULACEAE. **Columbia monkshood.** Western North America.

The writers' results are given on page 21.

Aconitum napellus L. **Aconite.** Old World.

Gomilevsky (*28*) determined that a few drops of a strong water extract, dropped upon the body of a stag beetle (*Lucanus cervus*), were fatal.

Aeschrion excelsa (Swartz) Kuntze. SIMARUBACEAE. Synonyms: *Picrasma excelsa* Planch., *Simaruba excelsa* DC., *Quassia excelsa* Swartz, *Picraena excelsa* Lindl. **Jamaica quassia.** West Indies.

The use of quassia wood as an insecticide is well known. See the paper by the writers (*60*).

Aesculus glabra Willd. AESCULACEAE. **Ohio buckeye.** Eastern United States.

Riley (*71, p. 184*) reports that an alcoholic extract of the fruit and an alcoholic extract and a decoction of the leaves had no effect on the cotton caterpillars tested.

Aesculus pavia L. **Red buckeye.** Southeastern United States.

Porcher (*68, p. 91*) says: "Bedsteads made of the horse-chestnut are said not to be infested by bugs."

Agave americana L. AMARYLLIDACEAE. **Centuryplant.** Tropical America.

Von Mueller (*91, p. 24*) reports that "The infusion of the leaves can be applied as an insecticide."

Agave lecheguilla Torr. **Lechuguilla.** Texas and Mexico.

Cook, Hutchison, and Scales (*17, p. 13*) and Cook and Hutchison (*18, p. 5*) found that infusions of the roots had only a slight effect on fly larvæ.

Agrostemma githaga L. CARYOPHYLLACEAE. **Corncockle.** Europe, adventive in the United States.

Cook, Hutchison, and Scales (*17, p. 13*) determined that an infusion had practically no effect on fly larvæ.

Ailanthus altissima (Mill.) Swingle. SIMARUBACEAE. Synonym: *Ailanthus glandulosa* Desf. **Ailanthus.** China, cultivated in the United States.

Riley (*71, p. 184*) reports that a decoction and an infusion of the leaves had no effect on cotton caterpillars.

Von Mueller (*91, p. 27*) reports that it checks the spread of the rosebug, which is destructive to the trees.

Allium sativum L. LILIACEAE. **Garlic.** Europe.

Howard (*43, p. 59*), quoting Celli and Casagrandi, says that the odor of garlic will kill mosquitoes if the air is saturated.

Aloe barbadensis Mill. LILIACEAE. Synonyms: *A. perfoliata vera* L., *A. vulgaris* Lam. Source of **Barbadoes aloes.** India to northwestern Africa, naturalized in West Indies.

Mason reports that powdered Barbadoes aloes was on one occasion found as effective as insect powder (see Kirby, *48, p. 241*).

Aloe ferox Mill. **Cape aloe.** South Africa.

Von Mueller (*91, p. 34*) reports that "The bitter sap, used for dressing wounds, keeps off flies very effectively."

Aloe spp.

Greshoff (*31, p. 154*) says that the resin from aloes is an insecticide.

Schreiber (*81*) ascertained that a strong decoction of aloes with soap added gave good results against certain lepidopterous larvæ and aphids.

Amanita muscaria (L.) Pers. AGARICACEAE. Synonym: *Agaricus muscarius* L. **Fly agaric.** Europe.

Chesnut (*14, p. 13*) reports that "As a fly poison it has been used in Europe for hundreds of years."

Amanita pantherina Fr. Java.

Lyons (*53, p. 29*) reports that it is used as a fly poison.

Ambrosia elátior L. ASTERACEAE. Synonym: *A. artemisiifolia* L. **Ragweed.** Eastern United States to British Columbia and Mexico.

Riley (*71, p. 184*) says that an alcoholic extract and a decoction had no effect on cotton caterpillars.

Ambrosia trifida L. **Great ragweed.** Ontario to Florida and Colorado.

Riley (*71, p. 184*) reports that a decoction, infusion, and an alcoholic extract had no effect on cotton caterpillars.

Amygdalus persica L. ROSACEAE. **Peach.** Old World.

Smith (*86, p. 33*) says that the decoctions of peach leaves, of the blossoms of Ailanthus, and of the oxeye daisy had no effect on the rosechafer.

The writers' results are given on page 21.

Anamirta cocculus (L.) Wight & Arn. MENISPERMACEAE. Synonyms: *A. paniculata* Colebr., *Menispermum cocculus* L., *Menispermum lacunosum* Lam. Fruit=Cocculus indicus or **fish-berries.** East Indies and Hindustan.

Greshoff (*33, p. 46*) reports that Bacon says that in the Philippines the fruit is used for an antiparasitic ointment, and Lyons (*53, p. 35*) lists it as a parasiticide.

Angelica sp. APIACEAE. **Angelica.**

Scott, Abbott, and Dudley (*83, p. 5, 13, 26*) determined that angelica root was ineffective against bedbugs, roaches, and clothes moths, and Abbott (*1, p. 7, 11*) found it of no value against chicken lice and the dog flea.

Añiliton.[4] Venezuela.

The writers' results are given on page 21.

Annona cherimola Mill. ANNONACEAE. Synonym: *A. tripetala* Ait. **Cherimoya.** Peru.

Greshoff (*31, p. 12*) reports that the seed is used as an insecticide.

Annona glabra L. **Pond-apple.** Tropical America.

Maisch (*54*) reports that the powder of the seed is used as an insecticide.

Annona reticulata L. **Custard-apple.** Tropical America.

Maisch (*54*) says that the use of this is similar to that just above.

Annona spinescens Mart. Brazil.

Greshoff (*31, p. 12*) reports that the seeds, either finely powdered or in the form of a decoction, are used as an insecticide.

Dragendorff (*22*) states that the pulp is used as a fish poison and for the killing of noxious insects.

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[4] Several specimens of material received bore only local names, and from such data it was impossible to identify the plants scientifically. These local names are catalogued alphabetically, and it is hoped that their botanic names may be learned subsequently.

Annona squamosa L. **Sugar-apple.** Tropical America.

Greshoff (*31, p. 11*), quoting Hartwich, says that the seeds are used against head lice, and Lyons (*53, p. 41*) says that they are used as a parasiticide.

Anthemis arvensis L. ASTERACEAE. **Corn camomile.** Europe, naturalized in the United States.

Kalbruner (*47*) says that the flowers were entirely inactive against flies.

Greshoff (*33, p. 157*) reports that the odor drives away mice and insects.

Anthemis cota L. Italy.

Passerini (*66, p. 42*) determined that the flower heads killed the dog flea, although very slowly, but had no practical effect on flies and ants.

Anthemis cotula L. Synonym: *Maruta cotula* DC. **Mayweed.** Europe, naturalized in the United States.

Garrigues (*25*) reports that a decoction of the leaves is said to destroy all species of insects.

The powdered flower heads (*3*) were very effective against bedbugs, fleas, and flies, but ineffective against grain worms and other caterpillars.

Kalbruner (*47*) says that the flowers were entirely inactive against flies.

Anthemis nobilis L. Synonym: *Chamomilla nobilis* Godr. **Common camomile.** Europe, cultivated and adventive in the United States.

Gieseler (*26*) reports that the flower heads have an action on insects similar to that of insect powder.

Kalbruner (*47*) says that they were entirely inactive against flies.

Cook and Hutchison (*18, p. 4*) found them ineffective against fly larvæ.

Anthemis tinctoria L. **Yellow camomile.** Europe, Asia.

Kalbruner (*47*) says that the flowers were entirely inactive against flies, and Passerini (*66, p. 42*) found them of no practical use against flies and ants, but they did kill the dog flea slowly.

Anthemis sp.

Howard (*44, p. 96*), quoting Cruz of Rio de Janeiro, says that camomile, used as a fumigant in rooms in which yellow-fever patients are confined, is absolutely efficient against mosquitoes (*Aëdes calopus*).

Arisaema dracontium (L.) Schott. ARACEAE. Synonym: *Arum dracontium* L. Indian turnip. **Dragonroot.** Canada and eastern United States.

Pammel (*64, p. 103*) says that the corm of the Indian turnip is somewhat acid and is used to kill insects.

Arisaema japonicum Blume. Japan.

Greshoff (*33, p. 19*) reports that the roots are used in Japan as an insecticide.

Arisaema tortuosum Schott. Himalayan region.

Greshoff (*31, p. 157*) reports that the roots are used as an insecticide.

Aristolochia cornuta Mast., **A. brasiliensis** Mart., and **A. elegans** Mast. ARISTOLOCHIACEAE. Brazil.

Greshoff (*31, p. 131*) reports that the insects visiting these three species are killed.

Artemisia absinthium L. ASTERACEAE. Synonym: *Absinthium vulgare* Lam. **Common wormwood.** North Africa and Europe; thoroughly established and common in eastern Canada and northern New England.

Von Mueller (*91, p. 55*) says that it is "recommended for cultivation as a preventive of various insect-plagues, even phylloxera."

Schreiber (*81*) and Goriainov (*29*) determined that various dilutions of extracts had only a slight effect on the insects tested.

Cook and Hutchison (*18, p. 4*) found that the powdered leaves had no effect on fly larvæ.

Artemisia tridentata Nutt. **Sagebrush.** Western North America.

The writers' results are given on page 21.

Asclepias curassavica L. ASCLEPIADACEAE. **Bloodflower.** Tropical America.

Manning (*56*) reports that the Indians of southern Mexico sweep the floors and walls of their huts with this and find that they are not troubled with fleas for some time afterwards, and Bergey (*10*), quoting McDougall, makes similar statements and reports that the odor of this milkweed when thus used has been found to check the spread of fleas in houses.

Asclepias tuberosa L. ASCLEPIADACEAE. **Butterflyweed.** Eastern North America.

Cook and Hutchison (*18, p. 4*) found that an infusion of the roots had a considerable effect on fly larvæ, but it was not efficient.

Asimina sp. ANNONACEAE. **Papaw.**

Howard (*44, p. 24*) reports that papaw trees have been planted to serve as a mosquito repellent, but they are of no value.

Aster linosyris Bernh. and **A. tripolium** L. ASTERACEAE. Europe.

Passerini (*66*) found the heads of these species inactive against flies.

Atropa belladonna L. SOLANACEAE. **Belladonna.** Southern Europe and Central Asia.

Riley (*71, p. 184*) found that an alcoholic extract and a decoction of the leaves had no effect on cotton caterpillars.

The writers' results are given on page 21.

Azolla sp. SALVINIACEAE.

Howard (*44, p. 25, 27*) and Smith (*87, p. 437*) report that certain water plants, such as Azolla, Lemna, and "Phu-lo," have been grown in water where mosquitoes breed, and it has been ascertained that these check the breeding of the mosquitoes to a limited degree by preventing the larvæ from getting air.

Balbec. (See footnote on page 26.)

The writers' results are given on page 21.

Baptisia tinctoria (L.) R. Br. FABACEAE. Synonym: *Sophora tinctoria* L. **Yellow wild-indigo.** Eastern United States.

Williams (*94, p. 916*) reports that the plants, when placed in the harness, keep flies from the horses, and Porcher (*68, p. 202*) makes similar statements about its use.

Riley (*71, p. 184*) says that an alcoholic extract and a decoction had no effect on cotton caterpillars.

Berberis aquifolium Pursh. BERBERIDACEAE. **Oregon hollygrape.** Synonym: *Mahonia aquifolium* Nutt. Western North America.

Cook and Hutchison (*18, p. 4*) ascertained that an infusion of the roots had a considerable effect on fly larvæ, but it was inefficient.

Bocconia cordata Willd. PAPAVERACEAE. Synonym: *Macleaya cordata* R. Br. **Pink plumepoppy.** Japan.

Greshoff (*31, p. 18*) reports that the decoction is used in Japan as an insecticide.

Bryonia alba L. CUCURBITACEAE. **White bryony.** Old World.

Gomilevsky (*28*) reports that the root and other parts can be used against aphids.

Caladium bicolor (Ait.) Vent. ARACEAE. South America.

Greshoff (*31, p. 158*) reports that the powdered leaves are used as an insecticide.

Callilepis laureola DC. ASTERACEAE. South Africa.

Greshoff (*33, p. 155*) reports that the powdered roots are used as an insecticide in Natal.

Cannabis sativa L. MORACEAE. **Common hemp.** Asia, cultivated in the United States.

Riley and Howard (*72, p. 223*) report that hemp combings or leaves, scattered among bags and heaps of grain in India, are effective against weevils.

Von Mueller (*91, p. 97*) says: "The hemp-plant serves as a protection against insects on cultivated fields, if sown along their boundaries."

Capsicum annuum L. SOLANACEAE. **Common redpepper.** South America, now widely cultivated.

Scott, Abbott, and Dudley (*83, p. 5, 14*) found that redpepper was ineffective against bedbugs and roaches.

Abbott (*1, p. 12*) found redpepper of no value against the dog flea.

Carapa guianensis Aubl. MELIACEAE. Synonym: *Xylocarpus carapa* Spreng. **Andiroba** or **carapa tree.** Guiana.

Greshoff (*33, p. 84*), quoting Peckolt, reports that the decoction is used as an insecticide.

Caryophyllus aromaticus L. MYRTACEAE. Synonym: *Eugenia aromatica* Baill. **Clovetree.** Tropical regions.

Scott, Abbott, and Dudley (*83, p. 13, 34*) found powdered cloves ineffective against roaches, but efficient against the larvæ of carpet beetles, and Abbott (*1, p. 7, 11*) found them efficient against chicken lice and the dog flea, although he does not recommend them on account of their high cost.

Cassia occidentalis L. CAESALPINIACEAE. **Coffee senna.** Widely diffused in tropical countries.

Riley (*71, p. 186*) reports that an alcoholic extract and a decoction had a slight effect on cotton caterpillars.

Scott, Abbott, and Dudley (*83, p. 13*) found *Cassia* (species not given) ineffective against roaches.

Cassia stipulacea Ait. Chili.

Greshoff (*31, p. 67*) reports that the leaves are used as an insecticide.

Catalpa bignonioides Walt. BIGNONIACEAE. **Catalpa.**

The writers' results are given on page 21.

Causia and Cebolleja. (See footnote on page 26.)

Herrera (*40, p. 21*) obtained no practical results by using both of these against the winged forms of fruit maggots.

Ceratotheca integribracteata Engl. PEDALIACEAE. Tropical Africa.

Greshoff (*33, p. 145*) says that the decoction is used in West Africa as an insecticide.

Cereus sp. CACTACEAE. **Cactus.**

Howard (*44, p. 74*) says that cactus leaves, made into a sticky paste and spread over the surface of the water, kill the larvæ of mosquitoes by asphyxiation.

Charcoal (kind not stated).

Scott, Abbott, and Dudley (*83, p. 13, 26*) found charcoal ineffective as a dust against roaches and ineffective as a fumigant against clothes moths.

Chelidonium majus L. PAPAVERACEAE. **Swallow-wort.**

Goriainov (*29*) determined that a decoction killed 4 per cent of the larvæ of *Malacosoma neustria* and 44 per cent of the *Vanessa urticae* tested.

Chenopodium ambrosioides L. CHENOPODIACEAE. Synonyms: *C. anthelminticum* L., *C. ambrosioides anthelminticum* A. Gray. **American wormseed.** Tropical America, naturalized in the United States.

Riley (*71, p. 186*) reports that an infusion and an alcoholic extract from the blossoms and green fruit had no effect on cotton caterpillars.

The writers' results are given on page 22.

Chilocoan or **Chilcoagua.** (See footnote on page 26.)

Herrera (*40, p. 21*) obtained no practical results by using this plant against the winged forms of fruit maggots.

Chrosperma muscaetoxicum (Walt.) Kuntze. LILIACEAE. Synonyms: *Amianthium muscaetoxicum* A. Gray, *Melanthium muscaetoxicum* Walt., *Zygadenus muscitoxicum* Regel, *Helonias erythrosperma* Michx. **Crow poison.** Eastern United States.

Elliott (*23*) says: "This plant is a narcotic poison, and is employed in some families for destroying the house-fly. The bulbs are triturated and mixed with molasses or honey, and the preparation is spread upon plates and placed in parts of the house most infested. The flies are soon attracted, and the poison takes effect while they are sipping it. They are perceived to stand unsteadily, totter, and fall supine. The flies, unless swept in a fire or otherwise destroyed, revive in the course of 24 hours."

Lyons (*53, p. 117*) says that the bulbs are used as an insecticide. The writers' results are given on page 5.

Chrysanthemum achilleae L. ASTERACEAE. Synonym: *Pyrethrum achilleae* DC. Italy.

Passerini (*66*) found that the opened flower heads had some effect on flies, fleas, and ants; they were not much inferior to those of *P. cinerariaefolium.*

Chrysanthemum caucasicum (Willd.) Pers. Caucasian region.

According to Bishop (*11*), Persian insect powder is made from this species, but more reliable authors deny this statement.

Chrysanthemum cinerariaefolium (Trev.) Vis. Synonym: *Pyrethrum cinerariaefolium* Trev. **Dalmatian insect flowers.** Dalmatia. Cultivated in Japan and California.

The powdered flower heads of this plant constitute the well-known Dalmatian insect powder, and the Insecticide and Fungicide Board of the United States Department of Agriculture (*57, p. 1*) recognizes it as one of the three species from which genuine insect powder is made.

Passerini (*66*) tested the powdered heads and leaves of this plant and 14 other species belonging to Asteraceae and concluded by saying that not one of the 14 species has properties so powerful or so swift in its action against the house fly (*Musca domestica* L.), or the dog flea (*Ctenocephalus canis* Curt.) or against ants (*Cremastogaster scutellaris* Oliv.), as has this species. He states that when all parts of the plant are reduced to powder, they are active; the leaves, stems, and roots in a somewhat less degree than the flower heads. Scott, Abbott, and Dudley (*83, p. 7, 10*) determined that powdered pyrethrum stems had little or no practical value against bedbugs and cockroaches. Scott and Abbott (*57, p. 81*) ascertained that the stems and bracts (small leaves) were ineffective against roaches. Abbott (*1, p. 8, 14*) found pyrethrum stems to have no value against chicken lice and the dog flea. Mr. Abbott, Entomologist, Enforcement of the U. S. Insecticide Act, authorizes the writers to use the following statement, taken from his unpublished notes: "Pyrethrum stems are inefficient against 6 species of ants, 9 species of aphids, bedbugs, 3 species of chicken lice, chicken mites, clothes moth larvæ,

dog fleas, house flies, mosquitoes, *Orthezia insignis*, red spiders, and roaches."

As early as 1879 and 1880 Riley's (*71, p. 174-180*) assistants used infusions, decoctions, and alcoholic extracts of pyrethrum against the cotton caterpillars and a few other insects. They report little or sometimes no success with the extracts thus obtained. Cory (*19*), after making several tests with a commercial alcoholic extract, prepared in the form of a heavy liquid soap, reports that it is a promising insecticide against aphids, but Hamilton (*37*) used some of it against the boxwood leaf midge and had no success. Juillet, Calavielle, and Ancelin (*46*) extracted pyrethrum with ether, alcohol, and carbon tetrachlorid, and then incorporated these extracts into soap solution. They believe that these soapy extracts are superior to all other insecticides used in viticulture against Cochylis and Eudemis.

The writers' results are given on pages 6, 10 to 21.

Chrysanthemum coccineum Willd. Synonyms: *C. roseum* Adam, *Pyrethrum carneum* Bieb. **Persian insect flowers.** Persia to Caucasus Mountains.

Von Mueller (*91, p. 121*) claims that this species yields the Persian insect powder, and this is one of the three species, recognized by the Insecticide and Fungicide Board of the United States Department of Agriculture (*57, p. 1*), from which genuine insect powder is made.

Chrysanthemum coronarium L. **Crown daisy.** Mediterranean region.

Kalbruner (*47*) says that the flowers of this were entirely inactive against flies.

Chrysanthemum corymbosum L. Synonym: *Pyrethrum corymbosum* Scop. Europe, Asia, Africa.

Kalbruner (*47*) says that the flowers were feebly benumbing to flies.

Böhmer (*12*) states that a powder made from the opened and unopened flower heads, dried in the sun, was slightly less active than insect powder against ants and flies.

Passerini (*66*) did not find the opened flower heads of much value against flies, the dog flea, and ants.

Chrysanthemum frutescens L. **Marguerite.** Canary Islands, cultivated in gardens.

Landerer (*52*) claims that the flowers of this can ordinarily be substituted for genuine insect powder.

Chrysanthemum indicum L. **Mother chrysanthemum.** China and Japan.

Passerini (*66*) found the open and closed flower heads and the leaves of this species entirely inactive against the insects tested.

Chrysanthemum leucanthemum L. Synonym: *Leucanthemum vulgare* Lam. **Oxeye daisy.** Europe and Asia, naturalized in eastern United States.

Kalbruner (*47*) found the flowers entirely inactive against flies.

Riley (*71, p. 180*) found the powder, water extract, and alcoholic extract from the flower heads had no effect on cotton caterpillars.

Cook, Hutchison, and Scales (*17, p. 21*) found that this species had no effect on fly larvæ.

The writers' results are given on page 22.

Chrysanthemum marschallii Aschers. Synonym: *Pyrethrum roseum* Bieb. **Caucasian insect flowers.** Caucasian region.

This is one of the three species, recognized by the Insecticide and Fungicide Board of the United States Department of Agriculture (*57, p. 1*), from which genuine insect powder is made.

Chrysanthemum myconis L. Mediterranean region.

Passerini (*66*) says that the flower heads killed dog fleas, although very slowly.

Chrysanthemum parthenium (L.) Pers. Synonyms: *Matricaria parthenium* L., *Pyrethrum parthenium* J. E. Smith. **Feverfew.** Europe, adventitious in the United States.

Glover (*34, p. 133*) says that when the flowers are dried and perfectly fresh they have an effect on roaches similar to that of insect powder.

Kalbruner (*47*) found the flowers to have a benumbing effect on flies, acting within one or two hours.

Passerini (*66*) says that the flower heads of *Pyrethrum parthenium* (L.) Bernh. were not effective against the insects tested.

Chrysanthemum segetum L. Synonym: *Pyrethrum segetum* Moench. **Corn-marigold.** Europe.

Landerer (*51*) says that this is used in Greece and is as effective as Persian insect powder, particularly when it is used in fumigating.

Cimicifuga racemosa (L.) Nutt. RANUNCULACEAE. Synonym: *C. serpentaria* Pursh. **Cohosh bugbane.** Eastern United States.

Sayre (*78*) says that the powdered roots, used as a dust, had no effect on crickets; and also used in the form of a fumigant, an alcoholic extract and an aqueous extract, they had little or no effect on the insects.

Cinchona succirubra Pavon. RUBIACEAE. Peru.

Cook and Hutchison (*18, p. 4*) ascertained that the powdered bark gave a fairly high percentage of mortality against fly larvæ, but it did not seem entirely efficient.

Citrullus colocynthis (L.) Schrad. CUCURBITACEAE. Synonyms: *Cucumis colocynthis* L., *Colocynthis vulgaris* Schrad. **Colocynth.** Asia, Africa, and southern Europe.

Greshoff (*31, p. 80*) reports that a decoction of colocynth serves as an insecticide.

Scott, Abbott, and Dudley (*83, p. 5, 13, 26*) found the pulp ineffective against bedbugs, roaches, and clothes moths, and Abbott (*1, p. 7, 11*) found it of no value against chicken lice and the dog flea.

Claviceps purpurea (Fries) Tulasne.

Gomilevsky (*28*) reports that a water extract killed aphids, Psylla, thrips, and probably also other sucking insects and those unprotected by hairs.

Cleistanthus collinus (Roxb.) Benth. & Hook. EUPHORBIACEAE. East Indies.

Greshoff (*31, p. 141*), quoting Biscoe in Indian Forester, says: "The bark must contain some poison property, for not only do white ants leave it severely alone, but it is used here for poisoning fish. The inner bark placed on sores of sheep and goats is efficacious in healing them and in destroying maggots."

Clibadium surinamense L. ASTERACEAE. Tropical America.

The writers' results are given on page 22.

Conium maculatum L. APIACEAE. **Poison-hemlock.** Europe.

Gomilevsky (*28*) reports that the infusion of flowers, leaves, and stems is effective against various insects.

Cook and Hutchison (*18, p. 4*) found the powdered fruit ineffective against fly larvæ.

Cracca villosa purpurea (L.) Kuntze. FABACEAE. Synonyms: *C. piscatoria* Lyons, *Galega purpurea* L., *G. piscatoria* Ait., *Tephrosia piscatoria* Pers., *T. purpurea* Pers. **Pacific fish-poison.** Old World.

Lyons (*53, p. 145*) says: "Fish poison, Auhuhu, Hola (Hawaii). Tropical regions generally. Plant has narcotic properties; used medicinally in India and to stupefy fish in islands of Pacific."

The writers' results are given on page 22.

Cracca sp. FABACEAE. Synonym: Tephrosia. Warm and tropical regions.

Roark (*75, p. 35*) says: "U. S. Patent 1242954. A compound for use as an insecticide and sheep dip is formed from sulphur soap and comminuted Tephrosia (Cracca) plants, seeds, or leaves. U. S. 1242955 specifies, for the same purpose, a benzine extract of Tephrosia (Cracca) 0.5 to 1, soap 4, and dilute alcohol 15 parts."

Croton eluteria (L.) Swartz. EUPHORBIACEAE. **Cascarilla.** Bahamas.

Howard (*44, p. 30*) reports that cascarilla bark, used as a fumigant in Bermuda, is a mosquito repellent.

Croton flavens L. West Indies and northern South America.

Thoms (*90*) says that this is reported to be an insecticide in Venezuela, but he found it to have no effect on roaches, flies or gnats.

Croton texensis (Klotzsch) Muell. Arg., **C. glandulosus** L., **C. capitatus** Michx., and **C. monanthogynus** Michx. **Crotonweed.**

Riley (*71, p. 186*) reports that decoctions from the leaves and blossoms of these species had no effect on cotton caterpillars.

"**Cube**"[5] (pronounced koo′-bay), **cuyi** or **cume.** Local names in Peru. Peru.

The writers' results are given on pages 6, 10 to 20.

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[5] The name "cube" is applied, in all tropical America, to several plants belonging to distinct genera, which are used as fish poisons. Among them are species of Jacquinia, and several plants belonging to the family Sapindaceae. The identity of the "cube" here referred to is not certain. It will be necessary to receive botanical specimens of the plant before it can be determined.—W. E. Safford.

Cytisus scoparius (L.) Link. FABACEAE. **Scotch broom.** Europe.

An infusion (*8*), made from fresh crushed broom tops, is recommended to kill the larvæ of cabbage butterflies. In France it has also been found very effective for removing Cochylis larvæ from vines and various caterpillars from apple trees.

The writers' results are given on page 22.

Dasystoma flava (L.) Wood. SCROPHULARIACEAE. Synonym: *Gerardia flava* L.

Porcher (*68, p. 509*) says: "This plant, it is said, will prevent the attacks of yellow and other flies upon horses."

Datura stramonium L. SOLANACEAE. **Jimsonweed.** Jamestown weed. A cosmopolitan weed.

Riley (*71, p. 184*) reports that neither the alcoholic extract from the dried seed or leaves, nor a decoction from the leaves, was effective against cotton caterpillars.

Fernald (*24, p. 10*) determined that a strong infusion of the leaves had no effect on potato beetles, rose beetles, or the larvæ of *Vanessa milberti.*

McClintock, Hamilton, and Lowe (*58, p. 233*) ascertained that the leaves, used as a fumigant, were effective against bedbugs, roaches, flies, clothes moths, and mosquitoes, but they were not efficient.

Sprenger (*88*) recommends the decoction as an insecticide.

Cook, Hutchison, and Scales (*17, p. 14*) determined that a sulphuric-acid extract of the leaves was of no value against fly larvæ.

The writers' results are given on page 22.

Delphinium ajacis L. RANUNCULACEAE. **Rocket larkspur.** Southern Europe, and cultivated in gardens.

Greshoff (*31, p. 8*) lists it as an insecticide.

Williams (*95*), after testing against bedbugs the extracts, derived from the seeds by using various solvents, decided that the insecticidal value of the seeds is due mostly to the oil present in them, while the alkaloid in them plays an insignificant part.

Delphinium bicolor Nutt. **Low larkspur.** Western North America.

The writers' results are given on page 22.

Delphinium brunonianum Royle. **Musk larkspur.** Himalayan region.

Greshoff (*31, p. 7*) reports that the juice is used to destroy ticks on animals.

Delphinium caeruleum Jacquem. Himalayan region.

Greshoff (*31, p. 7*) reports that the roots are used to kill maggots.

Delphinium consolida L. **Field larkspur.** Central Europe, cultivated in gardens and adventive in the United States.

Williams (*94, p. 875*) says: "A tincture, prepared by infusing an ounce of the seeds in a pint of alcohol * * * kills lice on the human head."

Porcher (*68, p. 18*) reports that the tincture of the plant is destructive to insects on children's heads.

Riley (*71, p. 114*), quoting a correspondent, says: "I have found the common larkspur an effective poison on insects."

Delphinium staphisagria L. **Lousewort.** Mediterranean region.

Hare, Caspari, and Rusby (*38*) say that this species is employed in medicine solely as a local application for the destruction of lice and the itch-mite.

Delphinium sp. **Larkspur.**

Osborn (*63, p. 175*) reports that Tenny recommends a decoction of the seed of common larkspur as an insecticide against the short-nosed ox louse.

Cook, Hutchison, and Scales (*17, p. 14*) found that a sulphuric-acid extract of the ground seed had a considerable effect on fly larvæ, and Cook and Hutchison (*18, p. 4*) obtained similar results by using an infusion of the ground seed, but none of these were efficient.

Derris elliptica (Wall.) Benth. FABACEAE. Malayan or **East Indian fish-poison.** Aker. Tuba. Malayan region.

See "Derris as an insecticide," by McIndoo, Sievers, and Abbott (*61*).

The results obtained during this investigation by the writers are given on pages 7, 10 to 20.

Derris uliginosa Benth. **Eastern fish-poison.** Old World Tropics.

Perredes (*67*) says: "In India it is known to act as a poison upon worms and the larvæ of insects which trouble the cultivators, whence the Marathi name Kirtána, or 'worm-creeper.'"

Howard (*44, p. 78*) reports that a decoction placed in water at the Wellcome Research Laboratories at Khartoum had considerable potency against mosquito larvæ, but also killed the fish present in the water.

Diospyros malacapai A. DC. EBENACEAE. Philippine Islands.

Greshoff (*31, p. 103*) reports the wood as an insecticide.

Echinops echinatus Roxb. ASTERACEAE. East Indies.

Greshoff (*33, p. 160*), quoting Burkill, says: "The roots are pounded and applied to the hair to destroy lice, also the powdered roots applied to wounds in cattle to destroy maggots."

Eucalyptus globulus Labill. MYRTACEAE. **Blue gum.** Victoria and Tasmania.

Von Mueller (*91, p. 192*) says: "Warren reports from San Francisco that branchlets of eucalyptus will drive mosquitoes and other insects out of rooms."

Eucalyptus spp.

Riley and Howard (*73, p. 268*) quote a correspondent who says that a few twigs or leaves laid on the pillow at night will secure perfect immunity against mosquitoes.

Sanders (*77, p. 344*) says that when a grove of eucalyptus is planted near the house mosquitoes never give annoyance in the house, but Howard (*43, p. 62*, and *44, p. 22*) states that eucalyptus trees are probably of no value as mosquito repellents.

Howard (*43, p. 59*), quoting Celli and Casagrandi, says that the fumes from the fresh leaves will kill mosquitoes if the air is saturated.

Scott, Abbott, and Dudley (*83, p. 5, 13, 26*) found the leaves ineffective against bedbugs, roaches, and the larvæ of clothes moths, and Abbott (*1, p. 7, 11*) found them ineffective against chicken lice and the dog flea.

Euonymus americanus L. CELASTRACEAE. **Brook euonymus.** Eastern United States.

Porcher (*68, p. 154*) says that the seeds are used in some places to destroy vermin in the hair.

Euonymus atropurpureus Jacq. **Wahoo.** Eastern United States.

Porcher (*68, p. 154*) says that this possesses properties similar to that above.

Euonymus europaeus L. **European burningbush.** Europe, adventitious in the United States.

Lyons (*53, p. 188*) lists this as an insecticide.

Eupatorium capillifolium (Lam.) Small. ASTERACEAE. **Dog-fennel.** Southeastern United States.

Roark (*75, p. 92*) states that Porcher reports this by saying: "It is used to keep off insects and bugs by strewing on the floors of cellars and dairies."

Eupatorium perfoliatum L. Synonym: *E. connatum* Michx. **Boneset.** Eastern United States.

Riley (*71, p. 184*) reports that the powdered leaves seemed obnoxious to cotton caterpillars, but an infusion from the leaves had no effect on them.

Eupatorium sp.

Greshoff (*31, p. 93*) lists this as an insecticide.

Euphorbia cotinoides Miquel. EUPHORBIACEAE. Guiana.

The writers' results are given on page 22.

Euphorbia marginata Pursh. Synonym: *Dichrophyllum marginatum* Klotzsch & Garcke. **Snow-on-the-mountain.** Minnesota to Texas.

Riley (*71, p. 186*) reports that a decoction was ineffective against cotton caterpillars.

Euphorbia spp.

Chesnut (*13, p. 407*) says: "The juice of *E. marginata* and *E. bicolor* is used to some extent in Texas to brand cattle, it being held to be superior to a red-hot iron for that purpose, because screw worms will not infect the fresh scar and the spot heals more readily."

Sprenger (*88*) recommends *E. biglandulosa* and *E. dendroides* as insecticides in the form of decoctions.

Goriainov (*29*) determined that a decoction of spurge (*Euphorbia* sp.) killed only 38 per cent of the *Malacosoma neustria* tested.

Fluggea leucopyrus Willd. EUPHORBIACEAE. East Indies.

Greshoff (*32*), quoting Dymock, says that the leaves are used as an insecticide.

Furcraea cubensis Vent. AMARYLLIDACEAE. Tropical America.

The writers' results are given on page 22.

Galinsoga parviflora Cav. ASTERACEAE. **Galinsoga.** South America, introduced in the United States.

The writers' results are given on page 22.

Gouania lupuloides (L.) Urban (synonym *G. domingensis* L.) and **G. polygama** (Jacq.) Urban (synonym *G. tomentosa* Jacq.). RHAMNACEAE. Tropical America.

Greshoff (*33, p. 107*) reports that both of these are used as insecticides.

Gymnocladus dioica (L.) Koch. CAESALPINIACEAE. Synonyms: *G. canadensis* Lam., *Guilandina dioica* L. **Kentucky coffeetree.** Eastern United States.

Von Mueller (*91, p. 248*) says: "Insects preying on the foliage of this tree are poisoned by it."

Chesnut (*14, p. 28*) reports that the leaves and fruit pulp have been used, when rubbed up with milk, to poison flies.

Pammel (*64, p. 117*) says: "In the South the leaves are used as fly poison."

The writers' results are given on page 22.

Haplophyton cimicidum A. DC. APOCYNACEAE. "**Cucaracha**" herb of Mexico. Arizona to Guatemala and Cuba.

Greshoff (*31, p. 107*) lists this as an insecticide.

According to the Experiment Station Record (*7*), "The cucaracha herb is reported as being an effective remedy for destroying lice and fleas on dogs, cockroaches, mosquitoes, and other insects. The pest plant costs 1 ct. [centavo] per kilo and may be used in infusion."

Herrera (*40, p. 21, 69–71, 188*) states that he had considerable success in poisoning Culex, Anopheles, various species of Instrypetas, and other Diptera by using the juice and infusion of the leaves, the juice and infusion of the entire plants, the maceration of the bark, and the concentrated alcoholic extract. He also states that an attempt has been made to cultivate this plant for the purpose of obtaining insecticidal material. The same author (*41, p. 247 et seq.*) summarizes the results of his earlier paper and furthermore describes the action of this plant on insects, names other plants similar to the herb of cucaracha, and briefly discusses the composition of the toxic principle found in these plants.

Hedeoma pulegioides (L.) Pers. MENTHACEAE. Synonym: *Cunila pulegioides* L. **American pennyroyal.** Eastern United States.

Riley (*71, p. 185*) states that the infusion, decoction, and alcoholic extract were ineffective against cotton caterpillars.

Lyons (*53, p. 223*) reports that it is used to drive away mosquitoes.

Helenium autumnale L. (**Sneezeweed**) and **H. tenuifolium** Nutt. (**Bitterweed**). ASTERACEAE. Eastern United States.

Riley (*71, p. 184*) reported that these plants rendered cotton plants so obnoxious to cotton caterpillars that the insects would not feed upon them, but the caterpillars were not killed. The decoction, infusion, and alcoholic extract were without effect, as were likewise the dried and powdered flower heads.

The writers' results, obtained by using the latter species, are given on page 22.

Heliotropium indicum L. BORRAGINACEAE. **India heliotrope.** Tropical regions.

Riley (*71, p. 186*) reports that a decoction had no effect on cotton caterpillars.

Helleborus niger L. RANUNCULACEAE. **Black hellebore.** Europe.

Cook and Hutchison (*18, p. 4*) found the powdered roots of *H. niger* inefficient against fly larvæ.

Hicoria glabra (Mill.) Britton. JUGLANDACEAE. Synonyms: *Juglans glabra* Mill., *Carya porcina* Nutt., *C. glabra* Spach. **Pignut.** Eastern United States.

Williams (*94, p. 920*) says: "An infusion of the leaves in water and washing a horse with them in fly time prevents the annoyance of those insects."

Hiptage madablota Gaertn. MALPIGHIACEAE. Tropical Asia.

Greshoff (*33, p. 84*) lists this as an insecticide.

Honduras fish-poison. (See footnote on page 26.)

The writers' results are given on page 22.

Hura crepitans L. EUPHORBIACEAE. **Sandboxtree.** Tropical America.

The writers' results are given on page 8.

Hyndocarpus anthelminthica Pierre. BIXACEAE. Tropical Asia.

Greshoff (*33, p. 112*) reports that the seeds are used as an insecticide.

Hyoscyamus niger L. SOLANACEAE. **Henbane.** Southern Europe, sparingly naturalized in the United States.

Sprenger (*88*) recommends decoctions of three species (*niger*, *albus*, and *major*) as insecticides.

Schreiber (*81*) found a strong decoction of henbane effective against aphids only.

Goriainov (*29*) found a decoction of henbane inefficient against two species of caterpillars and efficient against one species.

Ichthyomethia piscipula (L.) Hitchc. FABACEAE. Synonyms: *Piscidia erythrina* L., *P. piscipula* Sarg. **Jamaica fish-poison.** Jamaica dogwood. Jamaica.

Cook and Hutchison (*18, p. 4*) found that the powdered bark had considerable effect against fly larvæ.

Indigofera tinctoria L. FABACEAE. Synonym: *I. indica* Lam. **True indigo.** Tropical countries.

Porcher (*68, p. 205*) says: "In Jamaica, it is employed to destroy vermin."

Greshoff (*31, p. 52*) reports that the seeds yield a tincture which is used to destroy lice.

Inula conyza DC. ASTERACEAE. Synonyms: *I. squarrosa* Bernh., *Conyza squarrosa* L. **Cinnamon-root.** Europe.

Lyons (*53, p. 246*) lists it as an insecticide.

Inula viscosa (L.) Ait. Synonym: *Erigeron viscosus* L. Mediterranean region.

Landerer (*49*) reports that when this plant is used as a fumigant in Greece, it does not narcotize the insects but drives them away, and the same author (*50*) says that it is one of the most common plants of Greece. The fumes of the burning plant have the same stupefying effect on mosquitoes as those of Caucasian insect powder.

Passerini (*66*) found the flower heads inactive against flies.

Iris florentina L. IRIDACEAE. **Orris-root.**

Abbott (*1, p. 7, 12*) found orris root of no value against chicken lice and the dog flea.

Jatropha macrorhiza Benth. EUPHORBIACEAE. Mexico and southwestern United States.

The writers' results are given on page 22.

Juglans nigra L. JUGLANDACEAE. **Black walnut.** Ontario and eastern United States.

Porcher (*68, p. 362*) says: "Walnut leaves soaked in water for some hours, then boiled and applied to the skins of horses and other animals, will prevent their being bitten or worried by flies."

Riley (*71, p. 186*) reports that a decoction and an alcoholic extract had no effect on cotton caterpillars, but the insects avoided the sprayed leaves whenever possible.

Montillot (*62, p. 271*) reports that a decoction from walnut leaves, rubbed into the hair of domestic animals, protects these animals from house flies.

André (*2, p. 84*) reports that a decoction of walnut leaves poured on the woolly aphis and in the soil about the roots of orchard trees gives good results.

Guénaux (*35, p. 510*) reports that the infusion from walnut leaves is used to kill plant-lice and certain caterpillars.

Juniperus sabina L. PINACEAE. Synonym: *Sabina officinalis* Garcke. **Savin.** Old World.

Greshoff (*31, p. 161*) reports that a decoction of the tops serves as an insecticide.

Juniperus virginiana L. PINACEAE. **Redcedar.** Eastern United States.

Porcher (*68, p. 589*) says: "Cedar boxes are not infested by insects, moths, etc., and are used for storing away woolens. The leaves also prevent the attacks of insects when sprayed over cloth."

Scott, Abbott, and Dudley (*83, p. 28*) say: "A red-cedar chest readily killed all adult clothes moths and showed considerable killing effect upon young larvæ."

Back and Rabak (*9*) assert that cedar chests exert no noticeable effect upon the adult clothes moths, but they do kill the young larvæ. These writers indicate that the aroma from a volatile oil contained in the wood is the insecticidal principle.

Justicia adhatoda L. ACANTHACEAE. Synonym: *Adhatoda vasica* Nees. **Malabar-nut.** India.

Rusby (*76*) reports that it is fatal to flies, fleas, mosquitoes, and the pupæ of aquatic insects.

Kalmia angustifolia L. ERICACEAE. Sheep laurel. **Lambkill.** Eastern North America.

Cook and Hutchison (*18, p. 4*) found that the dried leaves had no effect on fly larvæ.

The writers' results are given on page 22.

Karwinskia humboldtiana Zucc. RHAMNACEAE. **Margarita.** Mexico.

The writers' results are given on page 22.

Lavandula spica L. MENTHACEAE. Synonym: *L. angustifolia* Mill. **Lavender.** Mediterranean region.

Scott, Abbott, and Dudley (*83, p. 28*) determined that lavender flowers were ineffective while the oil of lavender was effective in protecting flannel from clothes-moth infestation.

Ledum palustre L. ERICACEAE. **Crystal-tea.** Northern Europe.

It is reported from Austria (*4*) that this plant kills lice, bedbugs, fleas, moths, and other insects. It is most active when green and in blossom, but the dried material is also effective.

Lyons (*53, p. 266*) reports that the leaves and twigs of *L. palustre* L. are used as an insecticide.

Ledum groenlandicum Oeder. Synonym: *L. latifolium* Ait. **True Labrador-tea.** Northern North America.

Williams (*44, p. 916*) says that it is reported to kill lice, insects, etc.

Leontodon tuberosus L. ASTERACEAE. Synonym: *Thrincia tuberosa* DC. Old World.

Passerini (*66*) states that the opened flowers and roots were inactive against flies and the dog flea.

Linaria vulgaris Hill. SCROPHULARIACEAE. Synonyms: *L. linaria* Karst., *Antirrhinum linaria* L. **Common toadflax.** Europe, naturalized in the United States.

Williams (*94, p. 917*) says: "The expressed juice mixed in milk is a poison to flies, and the smell of the flower also kills them."

Lonchocarpus sp. FABACEAE. **Lancepod.**

The writers' results are given on page 23.

Lycium halimifolium Mill. SOLANACEAE. **Common matrimony-vine.** Europe, escaped from cultivation in the United States.

The writers' results are given on page 23.

Lycoperdon bovista L. LYCOPERDACEAE. Synonyms: *L. giganteum* Batsch., *L. caelatum* Fries, *Bovista giganteum* Nees. **Giant puffball.**

Greshoff (*31, p. 167*) says that it is "Used in its mature condition as a styptic and for stupefying bees."

Gomilevsky (*28*) reports that the spores may be used in the same way as flowers of sulphur. The insects covered with this powder either perish from its mechanical effects or are poisoned by it.

Lycopersicum esculentum Mill. SOLANACEAE. Synonyms: *L. lycopersicum* Karst., *Solanum lycopersicum* L. **Tomato.** South America, cultivated everywhere.

Von Mueller (*91*, *p. 509*) says: "Tomato foliage may be placed round fruit trees, like the equally poisonous potato leaves, to prevent the access of insects, and an infusion of the herb serves also as an insecticide for syringing, as first adopted by Mr. Sircy."

Makaida (*55*) claims to have determined in 1914 that tomatoes, planted near cucumbers, melons, and watermelons, protect these plants against aphids.

Schreiber (*80*) and Vostrikov (*92*) recommend the growing of tomatoes near cabbage beds to drive away cabbage butterflies, and they suggest the use of tomato extracts to control the cabbage caterpillars. Schreiber (*79*) suggests the use of a decoction of tomatoes against the pests of raspberries and dewberries.

Schreiber (*81*) found a concentrated extract of tomatoes very effective against aphids and various other market-garden pests, but Goriainov (*29*), also testing the decoctions of various plants against insects in Russia, carried on his experiments at the Entomological Bureau of Riazan and determined that a decoction of tomatoes gave only insignificant results against *Malacosoma neustria*.

Crouzel (*20*) says: "It is stated that an Italian vine grower, having planted tomatoes between the rows of vines in a vineyard badly infested with Phylloxera, was gratified to note fresh, healthy shoots break forth from the withered stocks, while numbers of dead Phylloxera insects were found around the roots of the tomato plants."

The writers' results are given on page 8.

Lycopodium complanatum L. LYCOPODIACEAE. **Groundcedar.** Europe, Asia, and North America.

Williams (*94*, *p. 924*) reports that the decoction kills lice.

Lycopodium selago L. **Fir clubmoss.** Northern hemisphere.

Greshoff (*31*, *p. 165*) lists it as an insecticide.

Lysimachia nummularia L. PRIMULACEAE. **Moneywort.** Europe, naturalized in the United States.

Porcher (*68*, *p. 509*) reports that the leaves and flowers, steeped in oil, have the power of destroying insects and worms which infest granaries.

Madhuca sp. SAPOTACEAE. Synonyms: Bassia, Illipe. East Indies.

The writers' results are given on page 23.

Marrubium vulgare L. MENTHACEAE. **Common hoarhound.** Europe and Asia, naturalized in the United States.

Riley (*71*, *p. 185*) reports that the decoction and alcoholic extract had no effect on cotton caterpillars.

Matricaria chamomilla L. ASTERACEAE. Synonyms: *Chrysanthemum chamomilla* Bernh., *Chamomilla vulgaris* S. F. Gray, *Chamomilla officinalis* Koch. **German false-camomile.** Europe and Asia, naturalized in the United States.

Schenck (*82*) reports that the flower heads of the common camomile have an action similar to that of genuine Persian insect powder.

Gieseler (*26*) says that heads of this plant exert an effect on insects similar to that exerted by pyrethrum.

Glover (*34, p. 133*) reports that camomile flowers, if pulverized when dried and perfectly fresh, have an effect on the oriental cockroach somewhat similar to that of pyrethum.

Hirschsohn (*42*) says that camomile powder is inert towards roaches.

Von Mueller (*91, p. 299*) says: "In Portugal it is planted under fruit trees for insecticidal purposes."

Scott, Abbott, and Dudley (*83, p. 5, 13*) found camomile flowers ineffective against bedbugs and roaches.

Passerini (*66*) says that the flowers kill lice, although very slowly, but that they have very little effect against flies and ants.

Matricaria inodora L. **Scentless false-camomile.** Europe, naturalized in the northern United States.

Kalbruner (*47*) says that the flowers have a benumbing effect on flies, acting within one or two hours.

Matricaria matricarioides (Less.) Porter. Synonyms: *M. discoidea* DC., *M. suaveolens* Buchenau. **Rayless false-camomile.** United States, naturalized in Europe.

Goriainov (*29*) found a decoction of camomile quite ineffective against *Malacosoma neustria.*

Meibomia laburnifolia (Poir.) Kuntze. FABACEAE. Synonym: *Desmodium laburnifolium* DC. Java.

Greshoff (*33, p. 72*) reports that the leaves are used as an insecticide.

Melanthium virginicum L. LILIACEAE. **Bunchflower.** Eastern United States.

Lyons (*53, p. 296*) reports that the roots are used as a fly poison.

Pammel (*64, p. 380*) says that "these bunchflowers have long been used to poison flies."

Melia azadirachta L. MELIACEAE. Synonyms: *Azadirachta indica* Juss., *Azedarach deleteria* Medic. **Nin tree.** East Indies.

Von Mueller (*91, p. 304*) says: "Furniture from its wood is not attacked by insects."

Melia azedarach L. Synonyms: *Azedarach commelini* Medic., *A. odoratum* Noronha. **Chinaberry.** Pride of India. China to India, cultivated in Florida.

Porcher (*68, p. 127, 200*) says that peach trees shaded by this tree are never infested by the aphis and that "the leaves and berries of the Pride of India, packed with dried fruits, will preserve them from insects, and will prevent moths in clothes." He further says that the decoction of the berries will, in most cases, prevent the depredations of the black grub, or cutworm.

Riley's (*71, p. 185*) assistants report that the decoctions and alcoholic extracts from the leaves, twigs, and berries were very promising. These preparations had considerable effect against cotton caterpillars, but failed to be efficient.

Von Mueller (*91, p. 305*) and Lyons (*53, p. 297*) report that the leaves are used as an insecticide.

Greshoff (*31, p. 31*), quoting Watt, says "a poultice of the flowers is said to kill lice."

Howard (*44, p. 25*) reports that chinaberry trees have been planted to serve as mosquito repellents, but that they are apparently useless.

The writers' results are given on page 8.

Mentha pulegium L. MENTHACEAE. Synonym: *Pulegium vulgare* Mill. European pennyroyal. **Pennyroyal.** Europe.

Von Mueller (*91, p. 308*) reports that it serves as an insecticide.

Mentha spicata L. Synonym: *M. viridis* L. **Spearmint.** Europe, naturalized in the United States.

Riley (*71, p. 186*) says that an alcoholic extract had no effect on cotton caterpillars.

Microsechium helleri (Peyr.) Cogn. CUCURBITACEAE. Mexico.

According to the Experiment Station Record (*7*) this plant is useful in destroying lice and underground insects.

Millettia auriculata Baker. FABACEAE. Himalayan region.

Greshoff (*33, p. 69*) says that the root is used as an insecticide.

Moetoepoe or **koetoepoe.** (See footnote on page 26.)

The writers' results are given on page 23.

Monarda punctata L. MENTHACEAE. **Spotted beebalm.** Horsemint. Eastern United States.

Riley (*71, p. 185*) says that an alcoholic extract from the leaves had no effect on cotton caterpillars.

Myrica cerifera L. MYRICACEAE. **Southern waxmyrtle.** Maryland to Florida, west to Texas.

Porcher (*68, p. 355*) reports that: "The Welsh lay branches of it upon and under their beds to keep off fleas and moths."

Myristica fragrans Houtt. MYRISTICACEAE. **Common nutmeg.** Molucca.

Howard (*43, p. 59*), quoting Celli and Casagrandi, says that the odor of nutmeg will kill mosquitoes if the air is saturated.

Necoetae. (See footnote on page 26.)

The writers' results are given on page 23.

Nelumbo lutea (Willd.) Pers. NYMPHAEACEAE. Synonym: *Nelumbium luteum* Willd. **American lotus.** Eastern United States.

Pammel (*64, p. 108*) says: "According to Schaffner it is said to be used to destroy cockroaches."

Nerium oleander L. APOCYNACEAE. **Common oleander.** Mediterranean region.

Greshoff (*31, p. 105*), quoting Schaer, reports that the bark is very frequently used for the destruction of rats and insects.

The writers' results are given on page 23.

Nicotiana glauca Graham. SOLANACEAE. **Tree tobacco.** South America, introduced in western United States.

Sprenger (*88*) recommends three species (*glauca*, *rustica*, and *tabacum*) of tobacco as insecticides.

The writers' results are given on page 23.

Nicotiana rustica L. **Aztec tobacco.** Eastern United States.

Goriainov (*29*) states that a decoction was an effective stomach poison against *Malacosoma neustria*.

Nicotiana tabacum L. **Common tobacco.** South America, now widely cultivated.

The writers' results are given on page 8.

Pachyrhizus tuberosus (Lamb.) Spreng. FABACEAE. West Indies.

Greshoff (*31, p. 57*), quoting Ernst, says: "The seeds (in decoction or in form of powder) are used in Merida (Venezuela) for killing vermin." He reports that the tubers and beans contain a poisonous resin which is an active fish poison.

Pangium edule Reinw. BIXACEAE. Java.

The writers' results are given on page 23.

Petunia sp. SOLANACEAE.

Sprenger (*88*) recommends a decoction of petunia as an insecticide.

Philadelphus coronarius L. HYDRANGEACEAE. **Sweet mockorange.** Europe, cultivated in the United States.

Riley (*71, p. 186*) states that an infusion, decoction, and an alcoholic extract had no effect on cotton caterpillars.

Physalodes peruvianum (Mill.) Kuntze. SOLANACEAE. Synonyms: *P. physalodes* Britton, *Atropa physalodes* L., *Nicandra physalodes* Pers. **Peruvian groundcherry.** Peru, cultivated and adventive in the United States.

Pammel (*64, p. 131*) reports it "used as a fly poison in parts of the United States."

Phytolacca americana L. PHYTOLACCACEAE. Synonym: *P. decandra* L. **Common pokeberry.** Ontario and eastern United States.

Glover (*34, p. 133*) reports that the root in either a fresh or dried state is poisonous to cockroaches.

One of Riley's (*71, p. 187*) assistants reports that a decoction of the leaves and berries and an alcoholic extract from the dried roots had no effect on cotton caterpillars; but another one of his assistants says that a very strong decoction "had a decided effect, killing the young worms and seriously affecting the older ones."

Cook and Hutchison (*18, p. 4*) found that the powdered root had no effect on fly larvæ.

Picrasma quassioides (Ham.) Bennett. SIMARUBACEAE. Synonyms: *P. ailanthoides* Planch., *Nima quassioides* Ham. Northern India.

Greshoff (*31, p. 30*), quoting Batchelor, says that a decoction of the bark is used to kill lice.

Lyons (*53, p. 356*) says that this species possesses insecticidal properties.

Pieris ovalifolia (Wall.) D. Don. ERICACEAE. Synonym: *Andromeda ovalifolia* Wall.

Greshoff (*31, p. 96*), quoting Watt, says that this is a useful insecticide.

Pilocarpus jaborandi Holmes. RUTACEAE. **Jaborandi.** Northern Brazil.

Cook and Hutchison (*18, p. 4*) found that the powdered leaves had a slight effect on fly larvæ.

Pimenta officinalis Lindl. MYRTACEAE. Synonyms: *P. pimenta* Karst., *P. vulgaris* Lindl. **Allspice.** West Indies and tropical America, cultivated everywhere in tropical countries.

Scott, Abbott, and Dudley (*83, p. 5, 13, 26, 34*) found powdered allspice ineffective against bedbugs, roaches, clothes moths, and carpet beetles, and Abbott (*1, p. 11*) found it of no value against the dog flea.

Pimpinella anisum L. APIACEAE. **Anise.** Southern Europe to the Levant; also cultivated.

Scott, Abbott, and Dudley (*83, p. 13*) found powdered anise seed ineffective against roaches.

Piper nigrum L. PIPERACEAE. **Black pepper.** India, cultivated in many tropical countries.

Graham-Smith (*30, p. 250*), quoting Howard, of Australia, says: "Flies may be effectively destroyed by putting half a spoonful of black pepper in powder on a teaspoonful of brown sugar and one teaspoonful of cream. Mix all together and place in a room where flies are troublesome, and it is said they will soon disappear."

Quaintance and Brues (*69, p. 133*), quoting tests made by Bishopp and Jones, say that black pepper had no effect on the oviposition of the bollworm when this substance was placed on the silk and ears of corn.

Riley (*71, p. 187*) states that a strong extract killed cotton caterpillars tested by contact within 12 hours.

Podophyllum peltatum L. BERBERIDACEAE. **Common mayapple.** Eastern United States.

Riley (*71, p. 187*) says that the powder from the dried roots did not affect cotton caterpillars when dusted upon them.

Pogogyne parviflora Benth. MENTHACEAE. California.

Chesnut (*15, p. 384*) says: "Many of the Indians place the culled plants in or about their houses to drive away fleas."

Polygonum hydropiper L. POLYGONACEAE. Synonym: *Persicaria hydropiper* Opiz. **Water-pepper.** Europe, United States.

Porcher (*68, p. 409*) quoting from Floria Scotica, states that it is found a convenient and useful application for driving off flies from wounds occurring on cattle.

Riley (*71, p. 185*) says that a decoction of the leaves and an alcoholic extract had no effect on cotton caterpillars.

Polygonum pennsylvanicum L. **Smartweed.** United States.

Washburn (*93, p. 35*) determined that a decoction had no effect on the horn fly.

Pongam pinnata (L.) W. F. Wight. FABACEAE. A tree found in India, Malayan Islands, and northern Australia, cultivated in Florida.

The writers' results are given on page 23.

Prunus spinosa L. ROSACEAE. **Blackthorn.** Sloe. Europe.

Von Mueller (*91, p. 430*) reports that it is hardly at all liable to attack by insects.

Pteridium aquilinum (L.) Kuhn. POLYPODIACEAE. **Bracken.**

In Austria the leaves are placed in the bed as a protection against vermin (*6*).

Pulicaria dysenterica (L.) Gaertn. ASTERACEAE. Synonym: *Inula dysenterica* L. **Fleawort.** Southern Europe.

Lyons (*53, p. 384*) calls it an herb insecticide.

Passerini (*66*) found the action of the flower heads uncertain against flies, fleas, and ants.

Pulicaria vulgaris Gaertn. Synonym: *Inula pulicaria* L. Europe.

Kalbruner (*47*) reports that the flowers were entirely inactive against flies.

Quillaja saponaria Molina. ROSACEAE. **Soapbark.** South America.

Parker (*65, p. 7*) used soapbark as a spreader and found that it never killed more than 21 per cent of the prune aphids sprayed.

Rhinanthus crista-galli L. SCROPHULARIACEAE. **Rattlebox.** Northern Europe, Asia, and North America.

Lyons (*53, p. 395*) lists it as a plant insecticide.

Rhus coriaria L. ANACARDIACEAE. **Sumac.** Europe.

Von Mueller (*91, p. 461*), quoting Sorauer, says: "Carvès records that this plant, when in proximity of vines infested by *Phylloxera vastatrix*, destroys this insect."

Reymond (*70*) buried a bag of sumac (*Rhus* sp.) leaves around the base of each apple tree infested with the woolly aphis (*Aphis lanigera*). He noticed no effect the first year, but the second year the experiment was very successful. He thought that the tannin in the ripe sumac leaves either killed or repelled the aphids.

Ricinus communis L. EUPHORBIACEAE. Synonyms: *R. vulgaris* Mill., *R. medicus* Forsk. **Common castor-bean.** Southern Asia.

It is reported (*5*) that in 1886 this plant was found efficacious in freeing rooms of insect life, the leaves containing a substance which is fatal to flies and other insects.

Riley and Howard (*74, p. 359*) quote a medical journal to the effect that in Egypt castor-bean plants, when grown about houses or when the leaves are placed in rooms where mosquitoes are present, are effective repellents, but Howard (*44, p. 23*) denies that these plants when grown about houses act as mosquito repellents.

Von Mueller (*91, p. 467*) says that these plants help drive mosquitoes away.

Cook and Hutchison (*18, p. 4*) found that the ground cake of the castor-bean had no effect on fly larvæ.

The writers' results are given on page 9.

Rosmarinus officinalis L. MENTHACEAE. **Rosemary.** Mediterranean region.

Von Mueller (*91, p. 472*) says: "Branches of this shrub will keep off moths from wearing apparel packed away."

Roylea elegans Wall. MENTHACEAE. Himalayan region.

Greshoff (*33, p. 138*) reports that the leaves are used as an insecticide.

Rumex sp. POLYGONACEAE.

Riley (*71, p. 186*) found that an alcoholic extract was ineffective against cotton caterpillars.

Ruta graveolens L. RUTACEAE. **Common rue.** Southern Europe.

According to Roark (*75, p. 102*), "A strong decoction obtained by macerating the leaves of the plant in soap and water, is stated by Forney to be a successful remedy for American blight."

Samadera indica Gaertn. SIMARUBACEAE. Synonyms: *S. pentapetala* G. Don., *Niota pentapetala* Poir., *N. commersoni* Pers.

Greshoff (*31, p. 30*) lists it as an insecticide.

Sambucus canadensis L. CAPRIFOLIACEAE. **American elder.** United States.

Porcher (*68, p. 448*) says: "A decoction made by pouring boiling water over the leaves, flowers, or berries of the elder is recommended as a wash for wounds to prevent injury from flies."

The writers' results are given on page 23.

Sambucus nigra L. **European elder.** Europe.

Porcher (*68, p. 449*) says that the leaves of the English elder are noxious to insects, moles, etc.

Greshoff (*33, p. 149*), quoting Cutler, 1785, says: "It is said, if fruits are whipped with the green leaves and branches of elder the insects will not attack them."

Santolina chamaecyparissus L. ASTERACEAE. **Lavender-cotton.** Mediterranean region.

Greshoff (*33, p. 158*) lists this as an insecticide.

Passerini (*66*) says that it killed the dog flea, although very slowly, but had practically no effect on flies and ants.

Sassafras variifolium (Salisb.) Kuntze. LAURACEAE. Synonyms: *S. sassafras* Karst., *S. officinale* Nees. and Eberm., *Laurus sassafras* L. **Sassafras.** Cinnamonwood. Eastern United States.

Porcher (*68, p. 391*) reports: "Bedsteads made of it are never infested with bugs."

Riley (*71, p. 186*) reports that an alcoholic extract of the dried bark of the roots had no effect on cotton caterpillars.

Abbott (*1, p. 7, 11*) found powdered sassafras bark very effective against chicken lice and the dog flea, but he does not recommend it against these insects.

Saussurea lappa (Decaisne) C. B. Clarke. ASTERACEAE. Synonyms: *Aplotaxis lappa* Decaisne, *Aucklandia costus* Falconer. **Costus root.** Himalayan region.

Von Mueller (*91, p. 492*), quoting De Rinzi, says that this plant is used as an insecticide to keep moths from cloth. The leaves are used as a wrapping for shawls.

Schkuhria abrotanoides Roth. ASTERACEAE. Peru to Argentina.

Haas (*36*) reports that the flowers of this are used in Peru for the same purpose as insect powder.

Von Mueller (*91, p. 497*) says that this annual herb yields locally an insecticide powder.

Schoenocaulon officinale (Schlecht. & Cham.) A. Gray. LILIACEAE. Synonyms: *Veratrum officinale* Schlecht. & Cham., *Helonias officinalis* Don, *Asagraea officinalis* Lindl., *Sabadilla officinarum* Brandt & Ratzeb. **Sabadilla.** Cebadilla. Mexico to Venezuela.

The use of sabadilla seed against lice seems to have been known for a long time. According to various botanical books, sabadilla powder is used by cattle raisers in Venezuela as an insecticide with excellent results.

Herrera (*40, p. 21*) had no success with it against the winged forms of fruit maggots (*Instrypetas ludens* I. D. B.).

McClintock, Hamilton, and Lowe (*58, p. 233*) ascertained that sabadilla seeds, used as a fumigant, had a slight effect on flies and clothes moths and a considerable effect against mosquitoes.

Scott, Abbott, and Dudley (*83, p. 5, 12*) ascertained that powdered sabadilla seed, used as a dust, killed from 95 to 100 per cent of the bedbugs treated within 48 hours; and used as a stomach poison (1 part to 9 parts of corn meal), it killed from 70 to 100 per cent of the roaches treated within 19 to 34 days.

Abbott (*1, p. 7*) found the powdered seed effective against chicken lice, but he does not recommend it because it is too expensive and not readily available in large quantities.

The writers' results are given on page 9.

Sericocarpus asteroides (L.) B. S. P. ASTERACEAE. **Whitetop-aster.** Eastern United States.

The writers' results are given on page 23.

Sideroxylon borbonicum A. DC. SAPOTACEAE. Bourbon Island.

Greshoff (*31, p. 101*) lists this as an insecticide.

Solanum auriculatum Ait. SOLANACEAE. Asia.

Greshoff (*33, p. 141*) reports that a decoction of the berries is used as an insecticide.

Solanum carolinense L. **Horsenettle.** Eastern United States.

Riley (*71*) found a decoction of this ineffective against cotton caterpillars.

The writers' results are given on page 23.

Solanum tuberosum L. **Potato.**

Gillette (*27, p. 185*) rubbed concentrated potato water on cattle and found that it acted slowly, but eventually it rid the animals of lice.

Scott, Abbott, and Dudley (*83, p. 14*) found potato starch ineffective against roaches.

Sophora flavescens Ait. FABACEAE. Siberia.

Greshoff (*33, p. 65*) reports that a decoction of the stems and leaves is used in Japan as an insecticide.

Sophora griffithii Stocks. Synonym: *Keyserlingia griffithii* Boiss.

Greshoff (*33, p. 65*) quotes: "The seed used powdered and mixed with oil kill lice in the hair."

Stipa viridula Trin. POACEAE. **Sleepy grass.**

The writers' results are given on page 23.

Suma rubra. (See footnote on page 26.)

The writers' results are given on page 23.

Synandrospadix vermitoxicus Engl. ARACEAE. Argentina.

Greshoff (*31, p. 158*) reports that the poisonous bulbs serve for the destruction of injurious insects.

Tagetes minuta L. ASTERACEAE. Synonym: *T. glandulifera* Schrank. South America.

Von Mueller (*91, p. 522*) says: "This vigorous annual plant is said by Doctor Prentice to be pulicifugous."

Tamus communis L. DIOSCOREACEAE. **Black-bryony.** Europe.

Greshoff (*31, p. 152*) reports that the powdered root has been recommended to destroy lice in children's hair.

Tanacetum vulgare L. ASTERACEAE. **Common tansy.** Europe and northern Asia, cultivated and naturalized in the United States.

Gieseler (*26*) reports that the heads exert an effect on insects similar to that of pyrethrum.

Kalbruner (*47*) determined that the flowers of this species were very feebly benumbing to flies.

Riley (*71, p. 186*) says that an alcoholic extract and an infusion had no effect on cotton caterpillars.

Martindale (see Kirby, *48, p. 241*) states that an action similar to that of Persian insect powder is produced by the common tansy, which is sold in the north of England for similar purposes.

Simmonds (*84, p. 202*) states that the flowers of tansy are said to have a stupefying effect on insects.

Devin (*21, p. 36*) says that he has heard it reported that a clump of tansies, growing about the base of the tree, gives perfect immunity against the plum curculio, but Slingerland (*85, p. 196*) says that tansy plants, grown near peach trees, have only a very slight effect on the peach-tree borer.

Trilisa odoratissima (Walt.) Cass. ASTERACEAE. **Carolina-vanilla.** Eastern United States.

Jackson (*45*) states that the leaves are used to protect woolen cloths from the attacks of moths.

Triticum sp. POACEAE. **Wheat.**

Scott, Abbott, and Dudley (*83, p. 14*) found wheat flour ineffective against roaches, and Abbott (*1, p. 7*) found it of no value against chicken lice, but McGregor and McDonough (*59, p. 65*) and others have found it to be an insecticide against the red-spider, although in this case it glues the mites fast to the foliage, thus causing death mechanically rather than by poisoning them.

Tropaeolum majus L. GERANIACEAE. **Common nasturtium.** Peru, cultivated in gardens.

Von Mueller (*91, p. 543*) reports that it has some insecticidal value, and it is even said that when planted around apple trees it will rid them finally of the woolly aphis.

Tssikoena. (See footnote on page 26.)

The writers' results are given on page 23.

Tylophora fasciculata Ham. ASCLEPIADACEAE. India.

Greshoff (*31, p. 108*) reports that the leaves and roots are used to destroy rats and other vermin.

Umbellularia californica (Hook. & Arn.) Nutt. LAURACEAE. Synonym: *Oreodaphne californica* Nees. **California-laurel.** California to Puget Sound.

Heamy (*39*) says that the tree is never attacked by insects, owing, as it is supposed, to the volatile oil it contains.

Chesnut (*15, p. 531*) says: "The leaves appear to be very valuable for driving fleas away."

Veratrum album L. LILIACEAE. **White false-hellebore.** White hellebore. Europe and northern Asia.

The powdered rhizomes and rootlets constitute the hellebore most generally used as an insecticide.

The writers' results are given on page 9.

Veratrum californicum Durand.

The writers' results are given on page 23.

Veratrum nigrum L. Old World.

Schreiber (*80, 81*) mentions this species and seems to think that it is as good as *V. album* for insecticidal purposes.

Veratrum viride Ait. Synonyms: *V. album viride* Baker, *V. album* Michx. American hellebore. **American false-hellebore.** Green hellebore. North America.

Von Mueller (*91, p. 556*) says that it serves like other Veratrums as an insecticide.

Cook, Hutchison, and Scales (*17, p. 17*) say: "There are three plants which are popularly called hellebore, namely, *Veratrum album*, *Veratrum viride*, and *Helleborus niger*. The term 'hellebore' is correctly applied only to *Helleborus niger*, which grows in

Europe and is not at the present time a commercial product in this country. The white and the green are the two commercial varieties, the white being largely imported, and the green the American plant. For insecticidal work these two varieties are considered equally valuable. The American hellebore (*Veratrum viride*), called 'swamp hellebore,' 'Indian poke,' and 'itch-weed,' is a common plant in wet ground and grows over a considerable area of the United States. The properties of this are said to be similar to those of white hellebore."

Verbascum blattaria L. SCROPHULARIACEAE. **Moth mullein.** United States, naturalized from Europe.

The writers' results are given on page 24.

Verbascum thapsus L. **Common mullein.** Europe and Asia, naturalized in the United States.

Riley (*71, p. 185*) states that an alcoholic extract and a decoction of the leaves were ineffective against cotton caterpillars.

Vernonia anthelmintica (L.) Willd. ASTERACEAE. East Indies.

Greshoff (*31, p. 92*), quoting Watt, says that the bruised seeds are largely employed as a means of destroying pediculi.

Vernonia noveboracensis (L.) Willd. **Common ironweed.** Eastern United States.

Riley (*71, p. 186*) states that the alcoholic extract and decoction were ineffective against cotton caterpillars.

Vitex agnus-castus L. VERBENACEAE. **Lilac chaste-tree.** Mediterranean region.

Greshoff (*33, p. 136*) reports that "flies are believed to avoid the tree, so that when they annoy people, branches of this tree are hung in the huts."

Weeds. (Species not stated.)

Thibault (*89*), after determining that insect powder would kill mosquito larvæ merely by being spread on the surface of water, then made a powder from weeds and grasses in the neighborhood and also found this powder to be an efficient mosquito larvicide. He decided that powders thus used killed mechanically, rather than by poisoning the larvæ.

Withania somnifera Dunal. SOLANACEAE. Mediterranean region.

Greshoff (*33, p. 143*) lists it as an insecticide.

Xanthium strumarium L. ASTERACEAE. **Cocklebur.** Europe and Asia, naturalized in the United States.

Riley (*71, p. 184*) says that a decoction and an alcoholic extract had no effect on cotton caterpillars.

Ximenia americana L. OLACACEAE. Synonyms: *X. inermis* L., *X. spinosa* Salisb. **Wild-olive.** Tallow-nut. Tropical regions.

Greshoff (*31, p. 32*) reports that "the crushed rind is frequently applied by the negroes in Africa to the sores of domestic animals to keep off the fleas."

Zanthoxylum clava-herculis L. RUTACEAE. Synonyms: *Z. carolinianum* Lam., *Fagara clava-herculis* Small (U. S. P.), *Z. fraxinifolium* Walt., *Z. tricarpum* Michx. Prickly ash. **Hercules-club.** Southeastern United States.

Riley (*71, p. 185*) reports that the powdered leaves seemed obnoxious to cotton caterpillars.

Zea mays L. POACEAE. **Indian corn.** Maize.

Chittenden (*16, p. 8*), quoting Bruner, says that corn meal, dusted on cabbage plants in the morning while dew is on, causes the imported cabbage worm to drop off and thus it protects the plants till washed off by the rain.

Scott, Abbott, and Dudley (*83, p. 13*) found corn meal ineffective against roaches, and Abbott (*1, p. 11*) found cornstarch ineffective against the dog flea.

Zygadenus venenosus S. Wats. LILIACEAE. **Zygadenus.** Western United States.

The writers' results are given on page 24.

GENERAL SUMMARY.

Since 1915 the writers have determined that the following species of plants, when properly prepared and used, are efficient against certain species of insects: Quassia (*Aeschrion excelsa*), amianthium (*Chrosperma muscaetoxicum*), pyrethrum or insect powder (*Chrysanthemum cinerariaefolium*), "cube," two species of derris (*Derris elliptica* and *uliginosa*), common tobacco (*Nicotiana tabacum*), sabadilla (*Schoenocaulon officinale*), and white false-hellebore (*Veratrum album*). Other writers report the following species of plants to be efficient against certain insects: Two species of *Chrysanthemum* (*coccineum* and *marschallii*), also used for making insect powder, clovetree (*Caryophyllus aromaticus*), *Claviceps purpurea*, "cucaracha" herb of Mexico (*Haplophyton cimicidum*), redcedar (*Juniperus virginiana*), and American false-hellebore (*Veratrum viride*).

The writers found the following plants to have some insecticidal properties, but they proved to be inefficient against the insects used in the tests: Balbec, a Honduras fish-poison, sandboxtree (*Hura crepitans*), margarita (*Karwinskia humboldtiana*), common matrimony-vine (*Lycium halimifolium*), tomato (*Lycopersicum esculentum*), *Madhuca* sp., chinaberry (*Melia azedarach*), moetoepoe, necoetae, *Pangium edule*, and common castor-bean (*Ricinus communis*). Other writers report the following plants to have insecticidal properties, but it is doubtful if any of them will prove efficient for practical work: Aconite (*Aconitum napellus*), *Aloe* spp., two species of *Anthemis* (*cota* and *tinctoria*), butterflyweed (*Asclepias tuberosa*), pepper (*Capsicum* sp.), swallow-wort (*Chelidonium majus*), three species of *Chrysanthemum* (*achilleae*, *myconis*, and *parthenium*), *Cinchona succirubra*, larkspur (*Delphinium* sp.), black hellebore (*Helleborus niger*), Jamaica fish-poison (*Ichthyomethia piscipula*), henbane (*Hyoscyamus niger*), German false-camomile (*Matricaria chamomilla*), Aztec tobacco (*Nicotiana rustica*), soapbark (*Quillaja saponaria*), lavender-cotton (*Santolina chamaecyparissus*), sassafras (*Sassafras variifolium*), and potato (*Solanum tuberosum*).

Of the 260 species of plants catalogued, 94 were found by the writers and others to have little or no effect as insecticides, and 109 other species are recorded by other writers as used for insecticides, but without citation of experimental evidence.

CONCLUSIONS.

Of the 260 species of plants catalogued, only about 5 per cent furnish material for efficient insecticides, and of these only about half may be regarded as satisfactorily efficient. The latter include three species of *Chrysanthemum* (*cinerariaefolium*, *coccineum*, and *marschallii*), used for making pyrethrum or insect powder; two species of *Derris* (*elliptica* and *uliginosa*); and a Peruvian plant known locally as "cube." The extracts of these, combined with soap, proved to be promising contact insecticides and compete favorably with nicotine sulphate in efficiency and probably in cost.

Relative to the other species catalogued, most of them are not worth further consideration. It does not seem at all probable that satisfactory insecticides can be obtained from the commoner weeds or flowers or from plants known to be only slightly poisonous to man or other animals; but with regard to the poisonous plants, particularly the fish-poisons, found in the Tropics or subtropics the chances to obtain other efficient insecticidal material are very promising.

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INDEX OF BOTANICAL AND COMMON NAMES OF PLANTS CATALOGUED.

[The numbers refer to pages; synonyms are italicized.]

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62

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UNITED STATES DEPARTMENT OF AGRICULTURE

In cooperation with the Nevada Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1218

Washington, D. C. ▼ July 21, 1924

HORSE-FLIES: BIOLOGIES AND RELATION TO WESTERN AGRICULTURE.

By J. L. WEBB and R. W. WELLS, *Entomologists, Investigations of Insects Affecting the Health of Animals, Bureau of Entomology.*

With a Description of the Mature Larva of *Tabanus punctifer*, by ADAM G. BÖVING, *Entomologist, Bureau of Entomology*, and a Description of a New Species, by JAMES S. HINE, *Professor of Zoology and Entomology, Ohio State University.*

CONTENTS.

HISTORICAL.

Blood-sucking flies of the family Tabanidae are very serious pests to horses, cattle, and other domestic animals. In certain cattle-growing sections of the United States, particularly where swampy areas exist, tabanids are pests of great economic importance.

In 1915, requests were received from cattlemen, through S. B. Doten, director of the Nevada Agricultural Experiment Station, for an investigation of the conditions favoring and the methods of controlling an abundance of horse-flies which were causing serious losses on ranches in Nevada. In that year J. H. Clemons, land commissioner for the Union Land and Cattle Co., one of the largest cattle

[1] F. C. Bishopp, of the Bureau of Entomology, directed the investigation, and Director S. B. Doten, of the Nevada Agricultural Experiment Station, cooperated. Most of the determinations were made by Prof. J. S. Hine. The junior author conducted the field work in 1919. In the field, Rufus Ogilvie assisted in 1917, Noble Waite in 1918, and Harold Whalman in 1919.

R. W. Wells, the junior author, resigned July 24, 1923.

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companies in Nevada, in a communication to Director Doten, stated that the flies were so numerous that they prevented the cattle from putting on flesh as they should, and that at times it seemed as though his company was more engaged in feeding flies than in feeding livestock. He stated that during the haying season flies swarmed over the horses, causing frequent runaways and serious accidents. Mr. Clemons believed, too, that the flies were active agents in spreading anthrax.

In 1915 F. C. Bishopp, directing the investigations of insects affecting the health of animals, Bureau of Entomology, United States Department of Agriculture, made a preliminary investigation of tabanid conditions in Nevada. In Antelope Valley, on one of the ranches visited, many cattle were dying, presumably from anthrax, and there was good evidence that blood-sucking flies had much to do with the transmission of the disease. Mr. Bishopp found tabanids to be serious pests to livestock at Deeth, Nev., and at other localities where there is considerable swampy land.

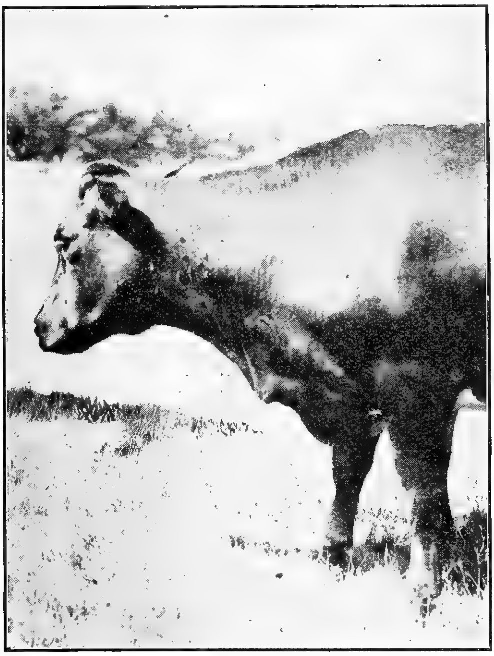


Fig. 1.—Horse-flies feeding upon milk cow.

In August, 1916, plans were completed with the Nevada Experiment Station for a cooperative project on an investigation of tabanid conditions. The senior author was chosen to conduct the studies in the field. Several localities were considered for field and laboratory studies. None seemed so well adapted as a large ranch occupying practically the entire Antelope Valley, lying partly in California and partly in Nevada, with headquarters at Topaz, Calif. The officials of the company, with major headquarters in Reno, Nev., were very anxious for the investigation. W. W. Cunningham, local manager, offered much in the way of convenience and assistance in the work. Several species of Tabanidae were very abundant in the valley and breeding conditions were apparently ideal.

The extent of the investigation, limited by lack of funds, is of more than local importance because several of the species studied are of rather wide distribution. It is hoped that the results may be an aid in much needed tabanid studies in other parts of the United States.

Because of the severe winter climate, the field studies were discontinued during the winter months.

INJURIOUSNESS AND ABUNDANCE.

LOSS OF BLOOD.

The loss of blood sustained by animals attacked by blood-sucking flies is considerable. It is estimated that eight flies of *Tabanus phaenops* Osten Sacken, or "greenheads," having fully fed upon an animal, take altogether 1 cubic centimeter of blood. *T. punctifer* Osten Sacken, a fly still larger, will take more blood than *T. phaenops*. During a season when tabanids are abundant, very commonly as many as 25 to 30 greenheads and 8 to 10 adults of *T. punctifer* are seen feeding on one cow (fig. 1). Considering that it takes a fly only about eight to ten minutes to complete its meal of blood, and that during one day an average of 25 to 30 flies may feed on the animal for six hours, the loss of blood could amount to 100 cubic centimeters in one day. This estimate is conservative. Many isolated animals, horses in harness, and animals too weak to fight the flies vigorously suffer a greater loss in blood than this.

FIG. 2.—Horses and mules grouped together for mutual protection from horse-fly attack.

LOSS OF FEED.

Another way in which the flies cause an important loss is by interfering with the feeding of the stock. During the time of day when flies are very abundant, from about 10 a. m. to 5 p. m., the horses and cattle cease feeding and bunch together for the purpose of fighting the flies (fig. 2.). In addition to the loss of feed during this bunching of the animals, many wounds result from hooking and kicking, and these become portals of infectious diseases or infestations by fly maggots. J. H. Clemons and W. W. Cunningham, cattle company officials, stated that the flies seriously retarded the fattening of the cattle.

CAUSE OF RUNAWAYS.

A considerable loss due to the flies is that from runaways of horses in harness. Mr. Clemons refers to several such accidents resulting in casualties as well as destruction to harness, machinery, and fences.

CARRIERS OF DISEASE.

Possibly even more serious than these losses is that due to various diseases transmitted and disseminated among domestic animals by tabanids.

In Louisiana and the southeastern part of Texas certain tabanids are popularly called "charbon flies." Mitzmain (*6*)[2] very clearly demonstrated in the Philippines that *Tabanus striatus* Fab. carried the trypanosome causative of the disease surra, from an infected animal to a healthy one. The same author (*7*) in 1914 reported the direct transmission of anthrax through the biting of *T. striatus*. Morris (*9*), in 1918, transmitted anthrax through the bite of *Tabanus* sp.

Boerner and Hartman (*1*), in 1914, in dealing with methods of suppression of anthrax in certain counties in Texas, were firmly convinced that tabanids had much to do with the epizootic. The anthrax bacillus was found by them in cultures of bacteria taken from the mouth parts, the feet, and from the ingested blood of these flies. In addition to this evidence, it was found that from 90 to 95 per cent of all the animals dying of anthrax in the five counties adjacent to where the flies were captured had local swellings on parts of the body most often attacked by this fly. Furthermore, unusual abundance of the fly was coincident with widespread epidemics of the disease.

In the Antelope Valley of California, where anthrax has often occurred, the same coincidence has been noted. It is a common opinion in the valley that the flies have much to do with transmission of the disease.

In 1906, the spread of surra among quarantined cattle imported from India was attributed by Mohler and Thompson (*8*) to the agency of *Tabanus atratus* Fab., some of which were feeding on the animals.

INFESTING MAN.

In Utah, during recent years, there have been several cases among human beings of what is known as the "deer-fly disease," commonly called that because histories of the cases usually revealed a bite from what is commonly known as the deer fly. That this fly, *Chrysops discalis*, is the carrier of the disease to man has long been suspected by physicians who have dealt with the malady. It remained, however, for Francis and Mayne (*2*) of the United States Public Health Service to demonstrate clearly the transmission of the disease by this insect.

ANTELOPE VALLEY.

Antelope Valley, lying partly in Nevada and partly in California, is about 23 miles long north and south (fig. 3). The valley is from 2 to 5 miles in width. It lies among the foothills of the east side of the Sierra Nevadas, about 65 miles south of Reno. The altitude at Topaz in the middle of the valley is about 5,400 feet.

CLIMATE.

The climate is typical of the semiarid valleys of the eastern slope of the Sierras. There is not sufficient rainfall to grow crops without irrigation. The growing season is comparatively short, being

[2] Numbers (*italic*) in parentheses refer to "Literature cited," p. 36.

limited to about five months of the year. In midsummer the days are hot but the nights cool, while the winter is extremely cold.

The West Walker River, rising among the snow-capped mountains to the west, flows through the valley, and it is from this stream that most of the water is obtained for the irrigation of the hay meadows and alfalfa fields which produce the principal crops.

Most of the valley, approximately 100 square miles, is owned and operated by one large land and cattle company with general headquarters at Reno. Several other large ranches in Nevada and California are operated by the same company. A few smaller and independent ranches are to be found along the west side of the valley. The headquarters of the large ranch are at Topaz, which is the name of the post office.

The major outputs of the valley consist of beef cattle, sheep, and wool. About 5,000 cattle, 18,000 sheep, and 1,000 horses and mules are wintered at the company ranch. As a necessary adjunct to the

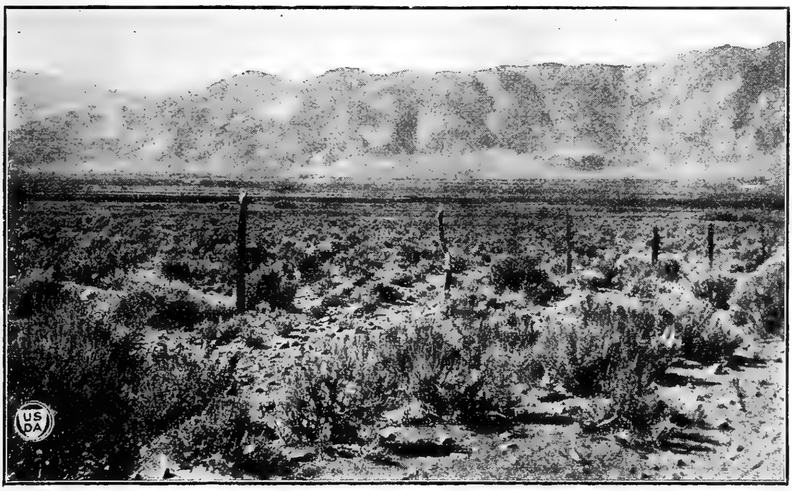


FIG. 3.—Antelope Valley of Nevada and California, from eastern side of valley looking southwest.

stock raising about 7,000 tons of hay are produced, 1,000 of which are alfalfa. Several hundred acres of oats and wheat were grown on the ranch in 1919.

IRRIGATION.

The summer precipitation in the valley being insufficient, the crops are absolutely dependent upon irrigation. On each side of the valley are two main supply ditches. Except during brief intervals for repair, water runs in these ditches continuously for irrigation in the summer and for watering stock in the winter. The sides of the valley slope considerably and from fields on these areas the irrigation water drains away rapidly. This waste water for the most part drains onto the more level part or floor of the valley and there finds such inadequate outlet that it accumulates in wide swampy areas and sluggish sloughs. Much of the floor of the valley is flooded from ditches to hasten the luxuriant growth of wild hay

and pasturage. This flooding, together with the wastage from higher areas, makes the floor of the valley a succession of swamps. In certain parts these swamps and sluggish channels are grown to tules. Areas slightly more elevated are grown to water grass and moss. In the fall of the year, when irrigation is discontinued, much of this semiswampy area affords wonderful pasturage; during the wet season it affords breeding places for an abundance of tabanids.

At the northwest corner of the valley proper, nature, fortunately in some respects and unfortunately in others, left a reservoir. In this low spot, from the irrigation of the northwestern part of the valley, has accumulated a body of water known as Alkali Lake, about a mile long and one-half mile wide (fig 4). The shores of this lake and the swampy area adjacent are choice breeding places of *Tabanus punctifer* and *T. phaenops*, the former being found abundant in moist humus near the edge of the water. The lake has no outlet.

FIG. 4.—Alkali Lake, Antelope Valley, looking south towards Topaz, Calif.

The intervals between irrigations of the more sandy land of the higher slopes of the valley average about two weeks. The flooding of the floor of the valley has no cessation until about the middle of the summer, when the water becomes more scarce. Then it is diverted into the higher ditches for the irrigation of the more important crops.

The ultimate destination of the overflowing wastage is the West Walker River, which runs through the valley. Provision of adequate drainage channels for this wastage is, as will be discussed later in this paper, one of the solutions of the tabanid problem.

BREEDING METHODS AND EQUIPMENT.

On account of the cannibalistic habit of tabanid larvæ, it was found necessary in rearing to isolate each larva. Glass fruit jars of 1 pint capacity were used for this. The disk of the cover was discarded and in its place a circle of galvanized wire gauze or screen was soldered into the ring (fig. 5). This arrangement admitted plenty of air and completed the isolation. In each jar was placed mud or débris similar to that from which the larva was taken in

nature. Water was added from time to time to approximate the natural amount of moisture. For food, small snails and earthworms were placed in the jars. The worms were usually cut into pieces 1 to 2 inches in length. The snails were introduced alive. Of the two the snails were of the most value as food. The larva would crawl into the shell and devour the entire contents. In making observations on the progress of the development of the larva the entire contents of the jar was dumped onto a white granite platter, where the search for the larva could be carefully made. Often it was found completely concealed within the shell of a snail.

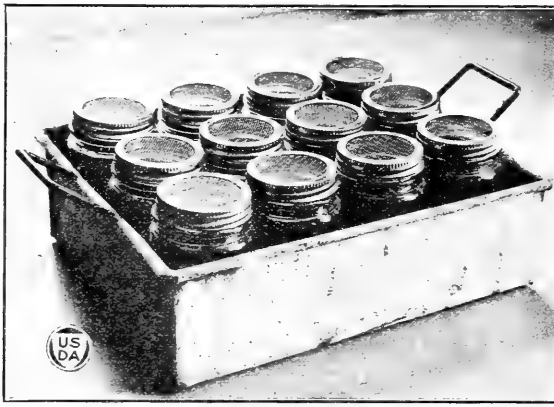


FIG. 5.—Jars used for rearing horse-flies.

The small one-room building constructed for the laboratory was widely open on each side and properly screened (fig. 6). This afforded good circulation of air.

At the beginning an attempt was made to duplicate soil temperatures and to provide a more uniform temperature than that which would result from leaving the jars exposed to the air. Galvanized-iron pans 4 inches deep and large enough to contain 12 jars were used. Water several inches deep was kept in the pans. This procedure was soon abandoned because time and facilities were not available to determine its value and because successful rearings could be made without it.

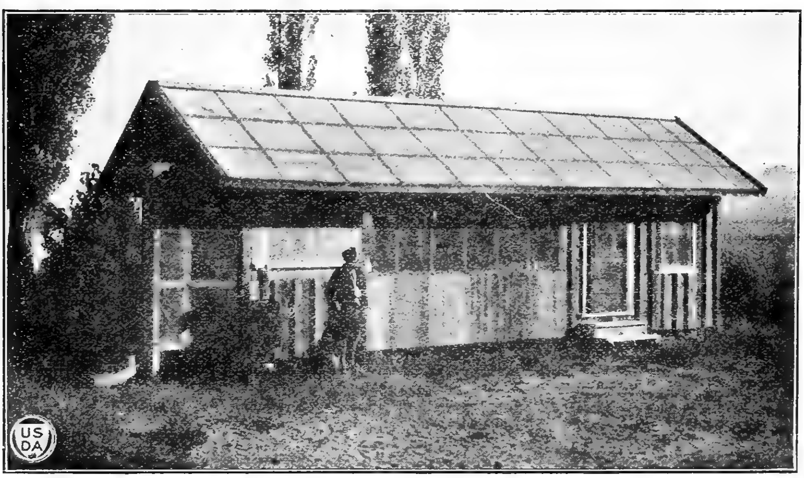


FIG. 6.—The field laboratory for horse-fly investigations at Topaz, Calif.

When the larvæ were in the prepupal stage or had already pupated no more water was added and the media usually became quite dry before the adults emerged. It was found that the adults would soon denude themselves if left more than an hour or so in the rearing jars.

Tabanid eggs collected in the field hatched very readily in the laboratory, but it was found that the period of incubation was considerably shorter in cases where they were exposed to high temperatures in direct sunlight. The eggs were taken to the laboratory on a portion of the vegetation or object to which the mass adhered and suspended over about a half inch of water in a glass vial an inch in diameter. A cotton stopper was placed in the vial to prevent any intrusion of predators or escape of emerging parasites. Upon hatching, the larvæ dropped to the water. *Tabanus punctifer* larvæ would remain near the surface; *T. phaenops* larvæ would remain more deeply submerged. The number of eggs was determined in most cases by counting the larvæ. In the case of badly parasitized egg masses the eggshells had to be counted. Egg masses of *T. phaenops* often became detached and dropped into the water, where they failed to hatch. This can be avoided largely by leaning the vials at an angle.

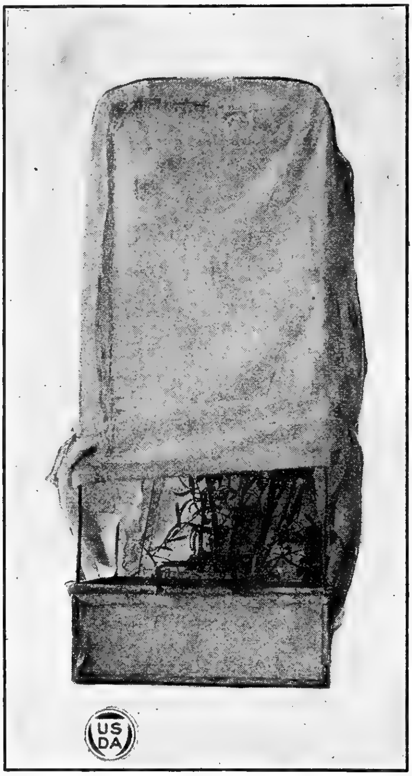
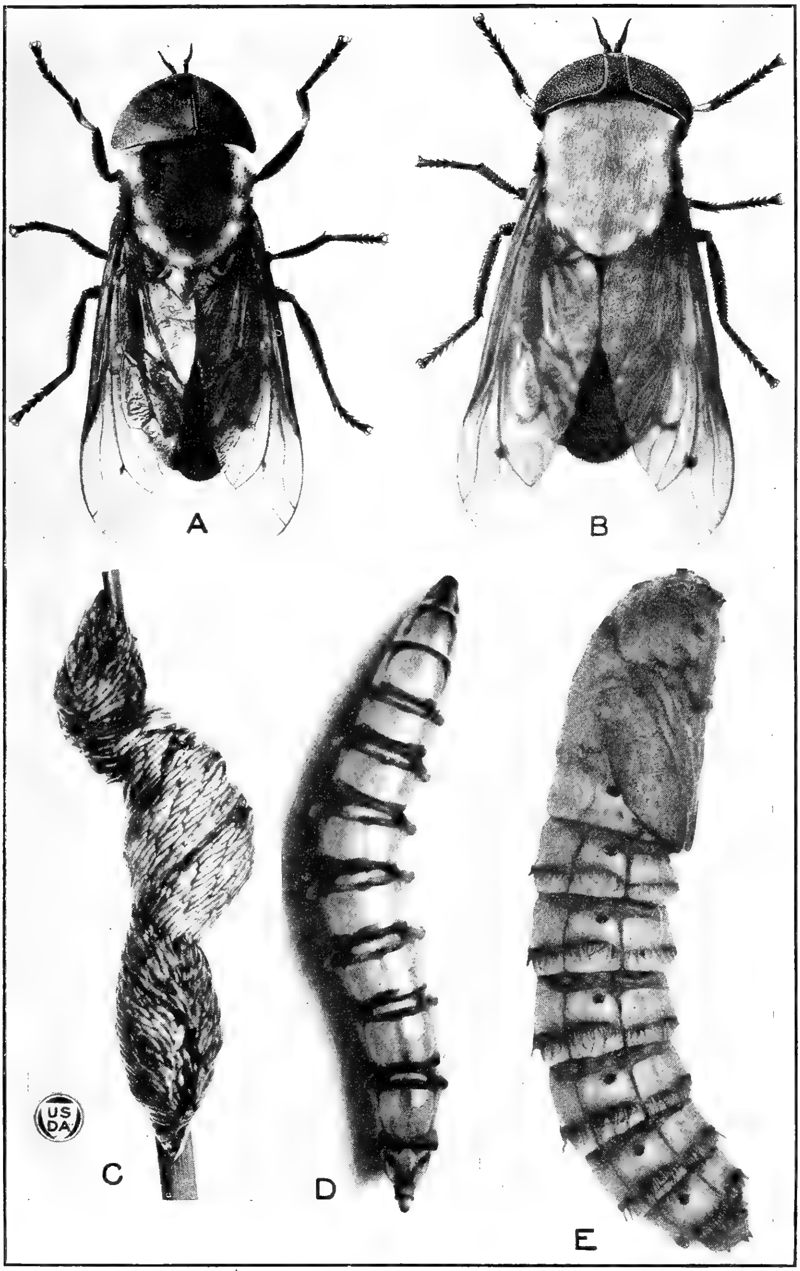


FIG. 7.—Oviposition cage used in securing horse-fly egg masses.

Larvæ collected in the field were placed with mud in vials or jars, several being in one container, and were carried to the laboratory with very little fatality.

OVIPOSITION CAGES.

It has been found very difficult to get *Tabanus punctifer* and *T. phaenops* to bite a host in captivity. A screen-wire cage 5 feet high and 10 feet square was constructed partly over water near a sluggish stream. The cage contained water plants and other vegetation upon which it was hoped the flies might oviposit. A calf 7 months old was placed in the cage September 1, 1917. About 300 flies (*T. phaenops*), including 8 or 10 males, were captured and released in the cage. The last flies were introduced September 11. On September 15 all were dead. No eggs were found and no flies were observed biting the calf. They appeared to be occupied in a constant effort to escape. Ovipositions were obtained, however, in a smaller cage (fig. 7). A rearing pan of galvanized iron 4



TABANUS PUNCTIFER.

A, adult male; *B*, adult female; *C*, egg masses, three masses upon a single stem; *D*, full-grown larva (living larva photographed by means of a special automatic flashlight device developed by S. B. Doten); *E*, pupa.

inches deep and 11 by 14 inches horizontally formed the base of the cage. A wire frame 18 inches high fastened to the corners of the pan supported the cheesecloth tent which was used for the caging. The lower end of the tent was closed by tying it with a string around the perimeter of the pan. A piece of soil containing moss, grass, and humus from a swamp was cut to the shape of the pan and placed within it, the grass and other plants extending into the tent above. Water nearly to fill the pan was added, and maintained at this level. Straws and pieces of sheet cork were placed around the edge of the island and slightly above the water.

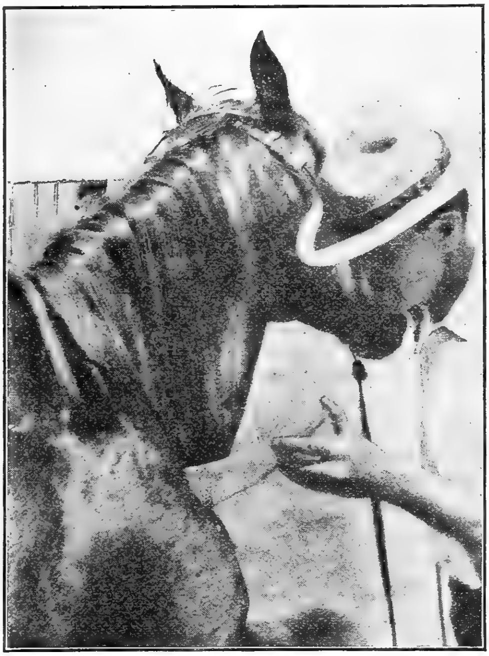


FIG. 8.—The feeding cone, showing method of capturing full-fed horse-flies.

FEEDING CONE.

Since *Tabanus phaenops* and *T. punctifer* are very reluctant to bite any host in captivity, it was necessary to capture some individuals which had been well fed in nature, in order to secure ovipositions. This was accomplished by the aid of a wire cone of ordinary house screen 3 inches in diameter and 8 inches long (fig. 8).

The point of the cone was cut off so as to allow an opening of about three-fourths of an inch. A gentle horse led into the field was good bait. After the fly had pierced the skin of the host and had begun feeding it was not easily disturbed. The large opening of the cone was then placed over it and so held. When the fly withdrew, which it usually did not do until it had become filled with blood, it was by careful manipulation made a captive. Through the small end of the cone it was transferred to a vial, carried to the laboratory, and released in the small oviposition cage previously described.

Rubber boots, hip length, were very essential. The extra-length boots, aside from their use in deep water, protected the knees when kneeling in swampy places in search of eggs and larvæ.

SPECIES INVOLVED.

The species of greatest economic importance in Antelope Valley are *Tabanus punctifer* (Pl. I) and *T. phaenops* (Pl. II). Other species found there are *T. insuetus* O. S. (Pl. III), *T. intensivus* Townsend, *T. productus* Hine (Pl. IV, *D*, *E*), *Chrysops coloradensis* Bigot (Pl. IV, *F*), *C. discalis* Will., *C. proclivus* O. S., and *C. surdus* O. S.

TABANUS PUNCTIFER Osten Sacken.

Description of Adult.

Tabanus punctifer (Pl. I), popularly known as the big black fly, is the largest fly commonly found in the Western States. Its general appearance is black, with the top of the thorax yellowish white.

The species was first described by Osten Sacken in 1875 (*11*), and because the publication is not generally available the author's description is quoted here in full:

Male and female. Head (♂) large, with distinctly separated large and small facets; front (♀) broad (broader than in *T. nigrescens*); frontal tubercle large, somewhat ill defined in outline and rather flat; antennæ black, projecting angle of the third joint rectangular; face brownish; palpi black. Thorax and scutellum, above, whitish or yellowish white, in consequence of a dense pollen, covered by a pubescence of the same color; pleuræ, pectus, abdomen and legs black, or dark brown; front tibiæ white at the base for more than one-third of their length. Wings brownish, especially on their proximal half; costal cell brown; a faint brown cloud on the crossvein at the base of the second posterior cell, which is not prolonged on the crossvein at the base of the third posterior cell; a dark brown round cloud at the bifurcation of the third vein. Length, ♂, 19 mm.; ♀, 19–20 mm. * * *.

This species is not unlike *T. stygius* Say, but is a little smaller, and easily distinguished by the white color of the base of the front tibiæ, the blackish or brownish, and not ferruginous brownish, wings, the absence of distinct white lines on the thorax, etc. The head of the male is much larger than in *T. nigrescens*, and the large facets occupy much more surface.

Unfortunately the males (Pl. I, *A*) are seldom seen in nature and are hard to capture. A good number were reared from larvæ, and these males differ markedly from the description given by Osten Sacken in the color of the dorsal vestiture. The dorsum of the thorax of the male, instead of being clothed entirely with yellowish white, has only a margin of that color, about 1.6 millimeters wide, surrounding a central area of black. This black spot appears in strong contrast with the whitish margin and is a very striking sexual distinction.

Distribution.

Osten Sacken gives the following:

West of the Rocky Mountains; Utah, Sonora, Calif., etc.; also Colorado (G. Ridings); seems to be a common species.

Specimens have been taken at Hunt, Ariz.; El Centro, Bishop, Bridgeport, Topaz, Chico, and Alturas, Calif.; and Deeth, Lovelock, Reno, and Carson City, Nev. The junior author has seen them in eastern Montana at Powderville, but has not collected them there. They were quite abundant in Antelope Valley and along the east side of the Sierra Nevada Mountains north of Bishop, Calif. In 1916 they were reported to have been exceedingly abundant at Wellington, Nev.

On account of less abundance, *T. punctifer* is considered of less economic importance than *T. phaenops*.

Abundance.

From reports and observations, *Tabanus punctifer* was more abundant in the summer of 1916 than during the three years fol-

lowing. August 25, 1916, 25 flies of this species were seen at one time attacking a pony.

The earliest appearances recorded for *T. punctifer* were May 28, 1919, at Lovelock, Nev., and at Topaz, Calif. On June 7, 1919, several were captured in Slinkard Valley, adjacent to and several hundred feet higher than Antelope Valley. The flies are most abundant during July and the first three weeks in August. During the last week in August they begin to decline in numbers and the latest one recorded was seen September 21, 1916.

Feeding Habits.

The females (Pl. I, *B*) of *Tabanus punctifer* attack horses and cattle eagerly, usually biting the animal along the back and, when numerous, on the jaws and neck. During the investigation there was only one instance of this fly biting man. On August 20, 1919, while the junior author was collecting at Alkali Lake, one bit him on the back through a heavy khaki shirt. The bite was exceedingly painful, being comparable to the thrust of a needle. The fly was captured in the hand. Horses make a most determined resistance to them. Cattle resist them less energetically; a cow lying down was observed to remain passive while a fly fed to repletion.

On July 29, 1919, *T. punctifer* was observed trying to feed upon carcasses. During the forenoon several attempted to feed upon the carcass of a cow dead for three days. Apparently they were unable to puncture the skin, because after several attempts they flew away. During the afternoon the carcass of a cow that had died only about an hour before was found. During the period of about one-half hour 14 *T. punctifer* were observed actually feeding on the carcass. This animal was suspected of having died of anthrax. On August 18 the carcass of a horse dead for several days was found in a ditch. The carcass lay half in water. Three *T. punctifer* attempted to feed, but the one captured and examined contained no blood. On one occasion a female attempted to feed upon a sack of forge coal. After inserting her mouth parts through the meshes of the burlap two or three times she flew away.

On account of the excitement and interruption usually attending a feeding of this fly in nature it was very diffcult to ascertain the actual length of time required for the ingestion of a full meal of blood. One accurate record is of special interest. On September 21, 1916, one was observed to alight upon a cow which was lying down. The cow was perfectly calm and the fly fed to apparent satiety in 11 minutes and 10 seconds.

Captured females refused to bite in captivity, as did also reared females, save in one case. Female No. 128 emerged August 21, 1919. On August 22 she was placed on a horse, a glass breeding jar being held inverted over her. She did not try to feed. On August 26 she was again placed on a horse. After brushing her labellum for half a minute with her forelegs she began trying to feed. She punctured the skin in four places, not feeding until the fourth puncture, where she fed for a period of 10 minutes, apparently continuously. While feeding her hind legs were extended in the air nearly parallel with the body; the first and second pairs of legs supported her on the

horse. During the feeding four droplets of clear fluid exuded from the anus. After feeding she again brushed the labellum with the forelegs and tried to fly. Her abdomen appeared to be fully distended with blood. This species was never observed among the stock much earlier than 4 a. m. or later than 5 p. m. It was most abundant and active between 10 a. m. and 3 p. m.

Both males and females of this species in captivity were very fond of sweets. They fed eagerly on after-dinner mints and on sugar solution.

Mating and Egg Development.

No mating of *Tabanus punctifer* was observed. The reared female No. 128 which emerged August 21 and which fed on the host on August 26 was then placed in an aquarium cage with several reared males. On September 4 the female was found dead lying on top of the soil in the cage. A *T. punctifer* larva was devouring the contents of her abdomen, which contained egg masses partly developed.

Oviposition.

No oviposition of this species was obtained in captivity. Egg masses were easily found in nature. They are attached to bulrush stems, coarse grasses, trunks of small trees (fig. 9; Pl. I, *C*) which grow in or hang over water, and occasionally to overhanging timbers of irrigation boxes. The distance of the eggs above the water varies from 1 to 3 feet.

Prof. A. C. Burrill reports one observation made in Idaho of *Tabanus punctifer* depositing a mass of eggs during "a hot August day, on the second strand of a barbed-wire fence midway between two posts and within 3 feet of water in the irrigation ditch parallel to the fence."

The senior author, on August 9, 1918, observed a female (No. 7693) of this species which had just finished ovipositing and was still in position, head downward. She was engaged in brushing the end of the abdomen over the mass, apparently distributing the cement with which the mass of this species is usually covered. The fly was not frightened away at the approach of the observer. The stem upon which she was resting was broken off and she was watched at close range for some little time before she flew away.

The egg masses were found most abundantly during August around the shore of Alkali Lake (fig. 9).

Egg Mass.

The egg mass of *Tabanus punctifer* (Pl. I, *C*) varies considerably in shape and size, depending upon the dimensions of the surface to which it is attached. When this surface is wide and flat the perimeter of the base of the mass is somewhat elliptical in shape, about 15 millimeters long and 10 millimeters wide. A mass attached to a slender object has a much narrower base. The eggs (fig. 10, *a*) are arranged in from three to five layers parallel to the base of the mass. Each layer has a perimeter slightly smaller than the layer preceding it, so that the mass has a pyramidal appearance. One mass of three layers measured 5 millimeters in thickness. Relative

to the base of the mass the eggs slant at an angle of about 45°, the mass usually being placed so that the distal end of the eggs points downward. A freshly laid mass is almost snow white. In a few hours this deepens to a whitish gray and becomes progressively darker, until on the third or fourth day it is nearly light brown. After hatching, the mass is light to dark brown. The mass is covered with a cement which helps to hold the eggs firmly together and possibly gives them some protection against predators and parasites, though the eggs of this species are heavily parasitized, as is discussed on page 31. The number of eggs in a mass varies from 200 to 800. The number of eggs was ascertained by counting the issuing larvæ, and since the masses in all but one case were parasitized the count of larvæ did not accurately indicate the number of eggs. The mass not parasitized contained 582 eggs. From one slightly parasitized mass, No. 7694, 701 larvæ were counted.

FIG. 9.—Along western shore of Alkali Lake, showing location of egg masses of *Tabanus punctifer*.

LARVA.

Before hatching the larva of *Tabanus punctifer* is ready to cast the skin of the first instar. Through the transparent eggshell can be seen the second instar within the exuvium of the first. Most of the larvæ when hatching carry the first exuvium to the water, where the molt is completed. The larvæ remain near the top of the water with the siphon to the surface.

DESCRIPTION OF THE FIRST EXUVIUM.

The first exuvium is 2 millimeters long. There are 11 body segments, 3 thoracic and 8 abdominal. The thoracic segments taper to the narrow diameter of the head capsule. The anal segment terminates with the pointed siphon, which, like the mouth parts, is shed when the larva molts. To many of the skins the molted siphon and mouthparts are hanging. Each segment, except the eleventh or anal, is provided around its anterior margin with from 5 to 10 rows of short spines. Along the venter this strip of spines consists of about 10 rows and along the dorsum of about 5 rows. The anterior end of the first thoracic segment is armed with spines for about one-third of its length. These spines and the ones in the spinose strips around the other two thoracic segments appear

to be longer and slightly less opaque than those on the abdominal segments. In front and at each end of the anal aperture are numerous spines. On the front half of each segment are scattered bristles. On each side of the mid-ventral line of each thoracic segment is a small tuft of 3 to 4 bristles varying in length. Dry mounts are the most satisfactory for studying these skins.

SECOND INSTAR.

Soon after the first molt of *T. punctifer*, the larva (fig. 10, *b*) is 2.7 to 3 millimeters long; the general color is creamy white; preserved in alcohol it becomes a pale yellow. The segmentation is the same as in the first instar. As in the full-grown larva, the head capsule telescopes into the two front thoracic segments. Each abdominal segment has a strip of yellow pile around both the anterior and posterior margins. The second and third thoracic segments have the yellow pile on only the anterior margins. The first thoracic segment into which the head capsule telescopes has yellow pile over the anterior and extending back over nearly half the segment. Each of the seven abdominal segments on its anterior margin has 6 tubercles, 3 in a line each side of mid-venter about equally spaced, the outer one being slightly below the midlateral line. The tubercle nearest the midventral line is circular, the outer two being oval. The tubercles are beset with stout spines and aid in locomotion. On the venter of each thoracic segment about midway are two tufts of 3 or 4 bristles like those described on the exuvium of the first instar. All the segments have numerous scattered bristles on the anterior half.

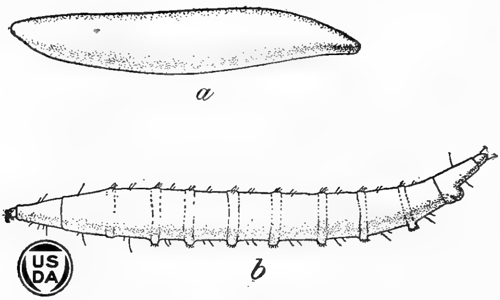


FIG. 10.—*a*, Egg of *Tabanus punctifer*; *b*, larva of *T. punctifer* after first molt. Greatly enlarged.

The anus is elliptical in shape, with long axis transverse. It has a margin of yellow pile which extends in a triangular area to near the midlateral line.

The siphon, slightly shorter than the anal segment into which it telescopes, is tubular and of constant diameter for two-thirds of its length. The posterior third narrows slightly to its circular end. The anterior end of the siphon has a wide margin of yellow pile. Where the tube narrows are four pairs of bristles, one pair on each side ventrally and one pair on each side dorsally. Several bristles are seen near the end around the opening.

In the anterior part of the anal segment above the anus Graber's organ (*5*) appears as two pairs of dark-colored globules. The anterior pair is the larger. They are dark brown and opaque. This observation was facilitated by using specimens cleared in hot five per cent caustic potash for 45 minutes. For study best results were obtained from alcoholic mounts. It was found very difficult to mount the specimens in balsam without great distortion.

DESCRIPTION OF MATURE LARVA.[3]

(Figs. 11–13; Pl. I, *D*)

Larva (mature) about 47 millimeters long, 5 millimeters wide; subcylindrical, elongate, tapering anteriorly and posteriorly; head well developed; thoracic segments 3; abdominal segments 8; two swollen, rounded anal lobes located ventrally on eighth abdominal segment, on each side of a longitudinal, almost vertical, anal slit (fig. 11).

Head.—Head (fig. 13) porrect, deeply retracted with about four-fifths of head capsule invaginated, entire head capable of complete withdrawal into thorax. Length of head capsule about 4.5 millimeters; width about 1 millimeter; sides parallel. Head capsule smoothly chitinized; ground color pale yellowish. Dorsal surface of capsule with long and rather broad, anteriorly and posteriorly attenuate, dark brown stripe on each side of epicranial suture; this stripe is accompanied, posteriorly and exteriorly, by a much shorter but almost as broad, spindle-shaped, dark-brown spot, and also medianly and

[3] By Adam G. Böving, Bureau of Entomology.

interiorly, very close to epicranial suture, by a fine dark-brown line. Lateral surface of head capsule with a dark fine line from middle of the main dorsal stripe to the point where tip of cardo attaches. Processes at anterior part of head capsule, and anterior tentorial arm (*D*), heavily chitinized, dark brown. Dorsally and laterally the head capsule is formed by fusion of the immovable labrum, the clypeus, the epistoma, the membranous bristle-bearing projection partly representing the frons, and the epicranium; posteriorly the capsule is closed by a convexly rounded wall limiting the occipital foramen behind, and ventrally it is bridged by the large median gular plate, limiting the occipital foramen in front. Occipital foramen ventral, large. All anatomical elements of the cranium are recognized principally by those criteria by which they are characterized throughout the entire insect class, sutures being present only to a very limited extent. Labrum about one-fifth the length of entire head capsule, very narrow, compressed, keel shaped, with dorsal surface bent downward like the bill of a bird of prey, whitish, membranous, with the inside enforced by one pair of long splinter-like chitinizations; posteriorly united with clypeus. Clypeus flat, ovate, almost circular, diameter about one-third the length of labrum; shiny yellow, with posterior one-third somewhat darker. Epistoma (*D*) characterized by socket with which mandible articulates dorsally; developed as separate sclerite, forming a strong frame on each side of clypeus; anteriorly prolonged as a slender process, which projects close to and along the side of posterior half of labrum; posteriorly flattened into a triangular plate. From the anterior margin of this latter (*D*), the aforementioned articulating socket projects on the inside, reaching forward as far as half the length of the slender process along the labrum; posteriorly and also on the inside of the epistoma the long, chitinous rodlike anterior tentorial arm attaches, extending posteriorly into the interior of the cranium, reaching and merging into the lateral border margin of the occipital foramen (*K*). Frons not developed as a definite structure. Epicranium occupying main part of entire head capsule, dorsally divided by the longitudinal median epicranial suture. Each epicranial half with process containing fossa for ventral mandibular condyle (*D*). Laterally and anteriorly the chitinous margin of the epicranium runs obliquely upward and outward from the base of process for dorsal mandibular articulation to the tip of process for ventral mandibular articulation. Articulating basal membranes of antenna and of mandible united with a membranous element, probably corresponding to angulus frontalis (a well-developed part of frons in many insect larvæ, for instance, the beetle larvæ), forming together a forward-extending structure very similar to an inflated bag (*I*). Dorsally this bag is attached to the anterior lateral chitinous margin of the epistoma; ventrally, along a V-shaped line, to the exterior part of basal margin of mandible; numerous conspicuous hook-like bristles set distally on the top; a short, straight, thick chitinous rod present in the ventral wall between the patch of bristles and the ventral articulating condyle of the mandible (*B*). The tendon of the mandibular exterior (=abductor or extensor) muscle developed from inner end of rod. Hypostomal margin of epicranium rather short, longitudinal, and curved, reaching from process for ventral mandibular condyle to the small cusp where the end of the cardo articulates. Gula a comparatively large plate, twice as long as wide, almost as long as labrum, shaped like a coat-of-arms, anteriorly with emargination; bridging the epicranial halves behind the posterior ends of the cardines. Tentorium represented only by the anterior tentorial arms mentioned and described above; tentorial bridge or posterior tentorial arms not developed. Optic spot single, dark, placed in the middle of oblique lateral line of epicranium. Antenna distinct, three jointed, with very small distal joint; long, slender, cylindrical middle joint placed anteriorly on the brownish, chitinized, somewhat arcuate, very flattened and posteriorly extended basal joint. Mandible compressed, vertical, separated into a distal and proximal division. Distal division (described by authors as the entire mandible) strongly chitinized, falciform, movably connected like the blade of a penknife with the proximal division; proximal division consisting of a

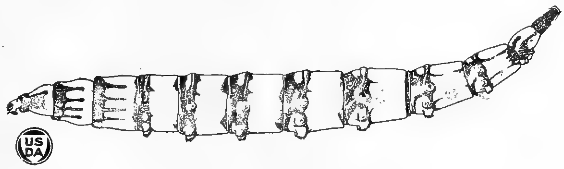


FIG. 11.—Full-grown larva of *Tabanus punctifer*.

large fleshy top region, developed as receiver for the distal division, and of a much smaller, strongly chitinized basal region; this latter contains the processes with the mandibular dorsal fossa and the ventral condyle, which articulate, respectively, with the dorsal and ventral articulating processes from the antero-lateral margin of the head capsule. The tendon of the interior mandibular muscle (=abductor or flexor mandibularis) extends from the inner corner of the basal region, and the exterior mandibular muscle (=abductor or ex-

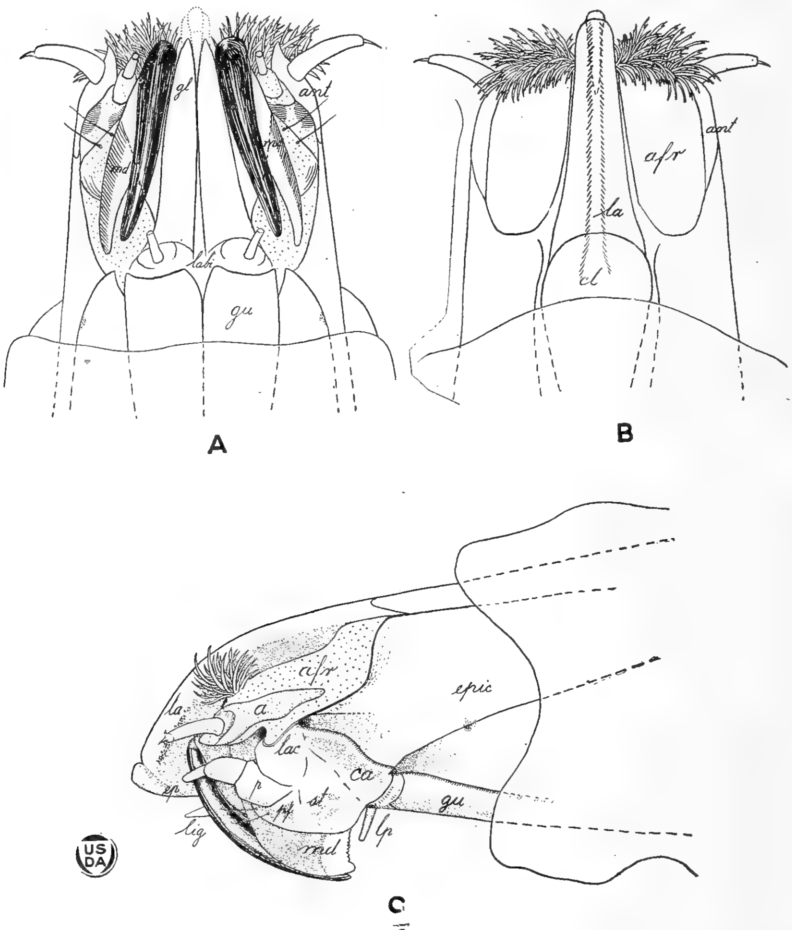


FIG. 12.—Mature larva of *Tabanus punctifer*. *A*, Anterior part of head from below; *ant*, Antenna; *gl*, glossa; *gu*, gula; *labi*, submentum, mentum, and stipes labii fused into small transverse membranous area. *B*, Anterior part of head from above: *afr*, Angulus frontalis; *ant*, antenna; *cl*, clypeus; *la*, labrum. *C*, Anterior part of head from side: *a*, Antenna; *afr*, angulus frontalis; *ca*, cardo; *ep*, epipharynx; *epic*, epicranium; *gu*, gular plate; *la*, labrum; *lac*, lacinia; *lig*, ligula (glossa); *lp*, labial palp; *md*, mandible; *p*, maxillary palp; *pf*, maxillary palpifer; *st*, maxillary stipes. Drawn by H. B. Bradford under supervision of Adam G. Böving.

tensor mandibularis) is, as previously mentioned, attached to the chitinous rod in the membranous process formed by the combined mandibular articulating membrane, membranous angulus frontalis, and antennal articulating membrane. Maxilla attached to epicranium along the hypostomal margin. Cardo and stipes hardly separated. Cardo whitish, entirely membranous, not much smaller than stipes. Stipes yellowish, divided into three sclerites of subequal size and more or less of subtriangular shape; one sclerite ventral and posterior, probably stipes maxillæ; the second, ventral and anterior, possibly palpifer; the

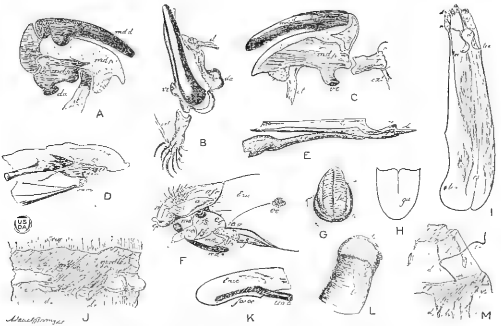


FIG. 13.—Mature larva of *Tabanus punctifer*. *A*, Mandible, dorsal side, appearing as the interior side in larvæ with vertically placed mandible as the present larva: *da*, Dorsal articulating process; *it*, tendon of interior mandibular muscle (or flexor); *mdp*, proximal part of mandible; *mdd*, distal part of mandible. *B*, Mandible, top view: *da*, Dorsal articulating process; *ext*, tendon of exterior mandibular muscle (or extensor); *it*, tendon of interior mandibular muscle (or flexor); *r*, rod in articulating membrane of mandible; *vc*, ventral condyle. *C*, Mandible, ventral side (appearing as the external side on account of the vertical position of the mandible): *ext*, Tendon of exterior mandibular muscle (or extensor); *it*, tendon of interior mandibular muscle (or flexor); *mdd*, distal part of mandible; *mdp*, proximal part of mandible; *r*, rod in articulating membrane; *vc*, ventral condyle. *D*, Head capsule, anterior portion from inside: *ata*, Anterior tentorial arm; *dam*, process for dorsal mandibular articulation; *cl*, process from epicranium extending alongside of labrum; *ep*, epipharyngeal skin; *ram*, process for ventral articulation of mandible. *E*, Paragnaths and hypopharyngeal chitinizations: *hch*, Hypopharyngeal chitinization; *li*, part of ligula (the right glossa removed); *oe*, oesophagus; *pg*, paragnath (=maxillulæ=paraglossa). *F*, Anterior part of head from the side: *a1*, Basal joint of antenna; *a2*, second joint of antenna; *a3*, apical joint of antenna; *afr*, angulus frontalis; *c*, cardo; *ca*, articulation of cardo; *cp*, epipharynx; *cpc*, epicranium; *g*, gular plate; *l*, lacinia; *li*, ligula; *lp*, two-jointed labial palp; *md*, proximal portion of mandible; *md**, distal portion of mandible; *mp*, maxillary three-jointed palp; *u*, labrum; *oc*, ocellus; *pf*, palpifer. *G*, Spiracle of eighth abdominal segment: *p*, Peritrema, the chitinous frame of spiracle; *tu*, air tube of spiracle. *H*, Gular plate (*gu*). *I*, Entire head from above and tilted a little to the right: *af*, Angulus frontalis; *at*, antenna; *cl*, clypeus; *e*, epistoma with *tea*; *es*, epicranial suture; *m*, maxilla; *oc*, ocellus; *tea*, anterior attachment of tentorial arm; *tep*, posterior attachment of tentorial arm. *J*, Fourth abdominal segment, right portion, flattened out: *a*, Ampulla; d_4, dorsal region; l_4, lateral region; *ms*, white spot where muscle is attached on inside; v_4, ventral region. *K*, Posterior part of head capsule: *epic*, Epicranium; *foroc*, foramen occipitale; *tena*, anterior tentorial arm (posterior portion). *L*, Spiracle and terminal part of trachea of eighth abdominal segment: *atr*, Atrium, the hair-filled air chamber below the air tubes; *h*, hair; *tr*, trachea (upper half removed); note the enforcing spiral in the wall; *tu*, air tube. *M*, Inside of prothorax and mesothorax, right portion, flattened out: *d*, Dorsal region; *l*, lateral region; *sp*, spiracle; *tr*, trachea; *v*, ventral region. (Drawn by Adam G. Böving.)

third, dorsal, with strongly chitinized concave, crescent-shaped marginal thickening, possibly lacinia. Maxillary palpus 3-jointed; all joints subequal in length, basal joint almost square, twice as wide as second, and second joint twice as wide as the apical one. Mentum, submentum, and basal region of labium representing stipes labii and palpiger labii, fused into a small, transverse, entirely membranous area in front of the gular plate and between the posterior parts of the cardines (*F*).[4] Labial palp small, with two yellowish, chitinized joints; basal joint very low, twice as wide as apical joints; apical joint comparatively long, cylindrical, slender, about same length and width as the apical joint of the maxillary palpus. Ligula as long as gular plate, half as wide; white and entirely membranous; apically bifid, forming two glossæ. The paragnaths of Snodgrass and Crampton (=the maxillulæ of H. I. Hansen and G. H. Carpenter=the paraglossæ auctorum) present behind the dorsal or buccal surface of glossæ; each paragnath forming a chitinized, small, well-defined sclerite, standing up as a longitudinal, short, triangular, compressed tooth (*E*). The buccal floor smoothly chitinized between the paragnaths. The hypopharyngeal chitinization anteriorly fused with the floor chitinization, but rising to a somewhat higher level; prolonged into a single, dorsally concave, ventrally convex rail which extends backward through the cranial cavity above the œsophagus and to which strong retractor muscles are attached. Epipharynx distally formed by a slightly chitinized, elongate-subovate minor part, proximally by a rodlike, anteriorly upward-curved major part. This latter part joins with the hypopharyngeal chitinization above the entrance to the œsophagus and at the point where the rail-shaped internal chitinization begins.

Segments of thorax and abdomen.—Prothorax and 8th abdominal segment conical with obtuse apices, respectively pointing forward and backward, subequal both in length, about 2 millimeters, and in width, about 1.75 millimeters. Mesothorax and metathorax subequal in size and general shape to the 7 anterior abdominal segments, each about 5 millimeters long and about 5 millimeters wide. Segments, in parts finely longitudinally striate, white anteriorly with a rather conspicuous dark girdle containing white spots corresponding to muscle attachments on the inside; metathorax and abdominal segments also with posterior dark, but less conspicuous, girdle. On each thoracic segment the border between the dorsal and lateral regions is marked by a dark, longitudinal, posteriorly pointed stripe from the anterior girdle; a similar marked border between the lateral and ventral regions; in the prothorax the lateral region is uniformly colored without any median longitudinal stripe, in the mesothorax and metathorax 2 such stripes are present (*M*); in the prothorax the ventral region has a single median longitudinal stripe, in the mesothorax and metathorax no ventral stripes. Abdominal segments without stripes, but located in the anterior girdle, dorsally with one low ampulla on each side, laterally with one large ampulla, ventrally with two large ampullæ. Ampullæ reduced in the eighth segment.

Spiracles.—Thoracic spiracles, one pair, very small, usually concealed within a vertical cleft, located laterally in the segmental boundary line between the prothorax and mesothorax. Abdominal spiracles, one pair, large, with a vertical spiracular slit, placed closely together at the end of a telescopically movable, posteriorly protruding, dorsal prolongation of the eighth abdominal segment.

PUPA.[5]

The pupa (fig. 14, *A*, *B*; Pl. I, *E*) is 28.5 to 33 millimeters long. The width of the thorax is 6 millimeters. Just after transformation the pupa is pale yellowish throughout. When nearing transformation to adult, the head turns black, and under the binocular the eye facets may be plainly seen through the skin. Dark areas also appear upon the prothorax, and the entire body is somewhat darker.

The head portion bears at the lower extremity of the anterior aspect, arranged upon opposite sides of the median line, two rounded, wedge-shaped, chitinous projections. Immediately laterad of these is a prominent tubercle, evidently the palpal sheaths. Posterior to the wedge-shaped teeth and somewhat remote from them are 2 prominent rounded chitinous tubercles, 1 at each

[4] The gular plate of the orthorrhaph larvæ has by recent authors been termed "submentum"; this interpretation is not correct, as the submentum always is located in front of the posterior end of the cardines, the gula behind.
[5] Description by J. L. Webb, Bureau of Entomology.

side of the median line, each bearing a bristle; considerably posterior to these are 3 smaller nonchitinous tubercles, the anterior one on the median line, the two others at each side and slightly posterior. Postero-laterad to these upon each side is a tubercle bearing a bristle. On latero-ventral aspect of prothoracic region posterior to wedge-shaped teeth 2 tubercles occur upon each side, each bearing a bristle.

Thoracic spiracle with rima broadly curved. In the female no hook occurs, but in the male a distinct hook occurs at the anterior end.

Each abdominal segment except the first and eighth bears a complete double circlet of bristles, the posterior circle being the longest. On the eighth, or anal segment, there is a dorso-lateral fringe of bristles, and in the male a continuous fringe of bristles on the ventral aspect, but in the female the ventral fringe is interrupted on the median line. Terminal teeth of anal segment about equal in size.

The descriptions of pupa and larva were made with the aid of a binocular microscope.

LIFE HISTORY.

EGG.

The egg of *Tabanus punctifer* averages 2.7 millimeters long and 0.5 millimeter thick (fig. 10, *a*). The basal part of the egg is more blunt than the distal part, which tapers to a small dimension. The shell has no thickenings or ridges. There is no operculum. When deposited the egg is snow-white.

INCUBATION.

Four accurate records were obtained of the incubation period of *T. punctifer*. They are given in Table 1.

TABLE 1.—*Incubation period of Tabanus punctifer.*

Date.	Egg mass.			Temperature during incubation.			Date.	Egg mass No. 8715.	Temperature during incubation.		
	No. 7693.	No. 7694, Breeding No. 1.	No. 7694, Breeding No. 2.	Max.	Min.	Mean.			Max.	Min.	Mean.
1918.				°*F.*	°*F.*	°*F.*	1919.		°*F.*	°*F.*	°*F.*
August 9	(1)	(1)	(1)	84.0	43.0	63.5	Aug. 13	(1)	92.0	42.1	67.0
10				85.0	43.5	62.2	14		93.0	44.2	68.6
11				84.0	42.0	63.0	15		95.0	45.3	70.1
12				87.0	37.0	62.0	16		96.0	55.7	75.8
13				82.0	44.5	63.2	17		93.0	49.0	71.0
14				79.0	40.0	59.5	18		94.0	49.0	71.5
15				79.0	42.0	60.5	19		96.0	44.2	70.1
16				77.0	33.0	55.0	20		98.0	48.3	73.1
17				71.0	35.0	53.0	21	(2)	98.0	48.8	73.4
18				74.5	38.0	56.2					
19				75.0	38.0	56.5					
20		(2)		80.0	33.5	56.7					
21				80.5	34.0	57.2					
22				73.5	34.5	54.0					
23	(2)		(2)	79.0	38.0	58.5					
Incubation period (in days)	14	11	14					8			
Average daily mean temperature	°*F.* 58.4	°*F.* 58.9	°*F.* 58.4							°*F.* 71.7	

[1] Deposited. [2] Hatched.

The mean temperature on the day of oviposition was not figured in the average mean.

No. 7694 was placed in direct sunlight on August 16 and kept there each day until hatching. No record was kept of the actual

temperature in the sunlight. With the higher mean temperature during the incubation of mass No. 8715, the incubation period was much shorter. The summer of 1919 was unusually hot. It is probable that in nature a few of these egg masses are in direct sunlight very much of the day. Hence the average incubation period in Antelope Valley is probably between 10 and 14 days. When hatching the larvæ burst open the shell somewhere near the distal end, and crawl actively out and drop into the water over which they have hatched.

LARVA.

No material or data were obtained to indicate the number of molts of *T. punctifer*. Mitzmain (7) gives three instars for *T. striatus* Fab., but on account of the vast difference in size between the second instar and the full-grown larva of *T. punctifer* there can be little doubt that there is an intermediate instar.

PUPA.

Accurate records were obtained on the pupal periods of 22 specimens. These are given in Table 2.

TABLE 2.—*Pupal periods of Tabanus punctifer.*

No.	Date of pupation.	Date of emergence.	Pupal period.	Sex.
			Days.	
6879–1	July 7, 1919	July 27, 1919	20	Female.
6896–1	July 8, 1919	July 25, 1919	17	Do.
7648–9	July 31, 1918	Aug. 28, 1918	28	Do.
10	Aug. 1, 1918	.....do........	27	Male.
13	July 8, 1918	July 24, 1918	16	Do.
129	July 29, 1919	Aug. 19, 1919	21	Female.
128	July 28, 1919	Aug. 21, 1919	24	Do.
140	Aug. 4, 1919	.....do........	17	Do.
141	Aug. 5, 1919	Aug. 23, 1919	18	Do.
142	July 25, 1919	Aug. 10, 1919	16	Male.
143	Aug. 8, 1919	Aug. 25, 1919	17	Do.
145	Aug. 9, 1919	.....do........	16	Do.
147	Aug. 12, 1919	Sept. 1, 1919	20	Do.
148	.....do........	Aug. 30, 1919	18	Female.
150	Aug. 13, 1919	Sept. 1, 1919	19	Do.
163	Aug. 16, 1919	Sept. 4, 1919	19	Do.
164	Aug. 18, 1919	Sept. 11, 1919	24	Male.
165	Aug. 16, 1919	Sept. 5, 1919	20	Female.
167	Aug. 17, 1919	Sept. 3, 1919	17	Male.
168	.....do........	Sept. 9, 1919	23	Female.
179	Aug. 21, 1919	Sept. 13, 1919	23	Male.
182	Aug. 24, 1919	Sept. 22, 1919	29	Female.

The average pupal period was 20.4 days. The average period for males was 19.6 days; for females, 21 days. It will be noted that the period was longer during the latter part of August and September when the temperatures were considerably lower. The temperatures are not given because they would not accurately represent temperatures of the soil in which the larvæ pupated.

Out of a large number of larvæ of *T. punctifer* reared from the egg only four pupated, and only three of these emerged as adults. Table 3 gives the duration of development.

TABLE 3.—*Developmental period of Tabanus punctifer.*

Date hatched.	Date of pupation.	Period of larval development.	Date of emergence.	Pupal period.	Sex.	Total period of development.
1917.		*Yr. Mo. Da.*	1919.	*Days.*		*Yr. Mo. Da.*
September 23	July 13, 1919	1 9 20	Died			
Do	July 1, 1919	1 9 8	July 18	17	Female	1 9 25
Do	July 29, 1919	1 10 6	Aug. 19	21	Female	1 10 27
Do	July 1, 1919	1 9 8	July 19	18	Male	1 9 26

Thus the developmental period in some cases is nearly two years. The larvæ were isolated in the rearing jars previously described. During the winter months they were cared for at the State experiment station at Reno, Nev.

HABITS OF THE LARVA AND PUPA.

Tabanus punctifer larvæ are cannibalistic, and in rearing them isolation is necessary.

Larvæ of this species were sometimes found in marshy areas and in the mud of sloughs. Several large ones were found in the loose gravel and sand a little above the edge of the water in an irrigation ditch. The ditch carries water all summer and part of the winter. The water is clear and cool and flows rather rapidly. These larvæ were found most abundantly, however, around the shore of Alkali Lake. They were almost always found a little above the water line, where waves kept the shore wet. Many were found in very coarse gravel and others in finely divided and decaying vegetation washed up on the shore. Always they were in very wet material. The water in this lake is somewhat alkaline, there being no outlet. A few fish are found in the lake.

In the rearing jars pupæ of *T. punctifer* were found near the surface of the medium, where there was less moisture. The pupæ were rather difficult to find in nature. On August 20, 1919, two pupæ were found along the west shore of Alkali Lake. They were about an inch below the surface in loose, fine gravel, fairly moist, approximately 8 feet away from the edge of the water, on a rather gradually sloping shore. The season being a dry one, the water line had been slowly receding, and possibly pupation took place slightly nearer the edge of the water. From these pupæ a male and a female emerged August 27, or seven days after collection. Hence they were pupæ of about 12 days when found.

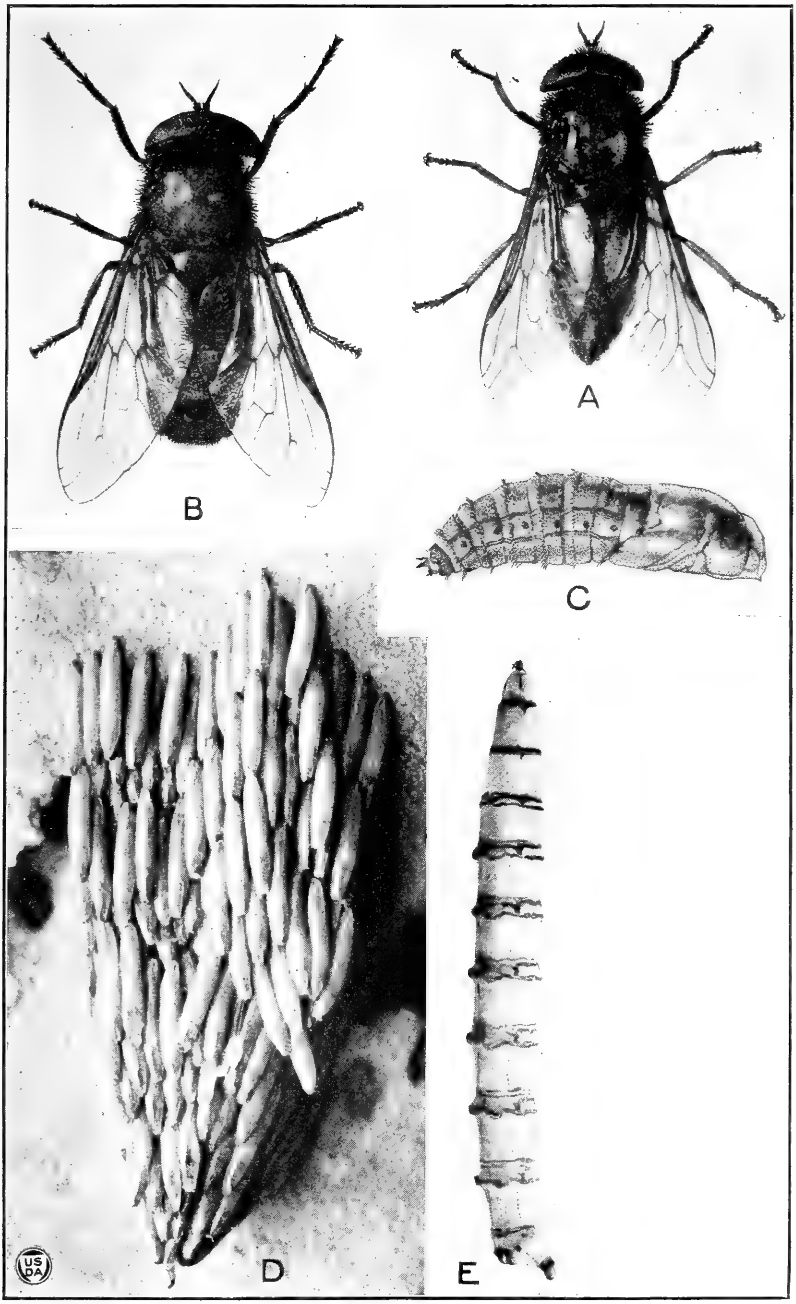
TABANUS PHAENOPS Osten Sacken.

DESCRIPTION OF ADULT.

Tabanus phaenops (*10*) is commonly known in Antelope Valley as the greenhead. The eyes are bright green, the thorax glossy black, and the abdomen broadly red on the side. (Pl. II, *A*, *B*.) It was described by Osten Sacken (*11*) in 1877. His description follows:

TABANUS PHAENOPS n. sp.—A *Therioplectes* of the same group with *T. sonomensis*.

Female.—Grayish-black; sides of the abdomen red; wings hyaline, no distinct brown cloud on the bifureation [bifurcation] of the third vein; antennæ black. Length 13–14$^{mm.}$



TABANUS PHAENOPS.

A, adult male; *B*, adult female; *C*, pupa; *D*, egg mass deposited on sheet cork (greatly enlarged); *E*, full-grown larva.

Front gray, a little converging; ocellar tubercle distinct; callosity nearly square, with a spindle-shaped prolongation above; antennæ black; third joint rather narrow, its upper angle very little projecting; thorax grayish-black,

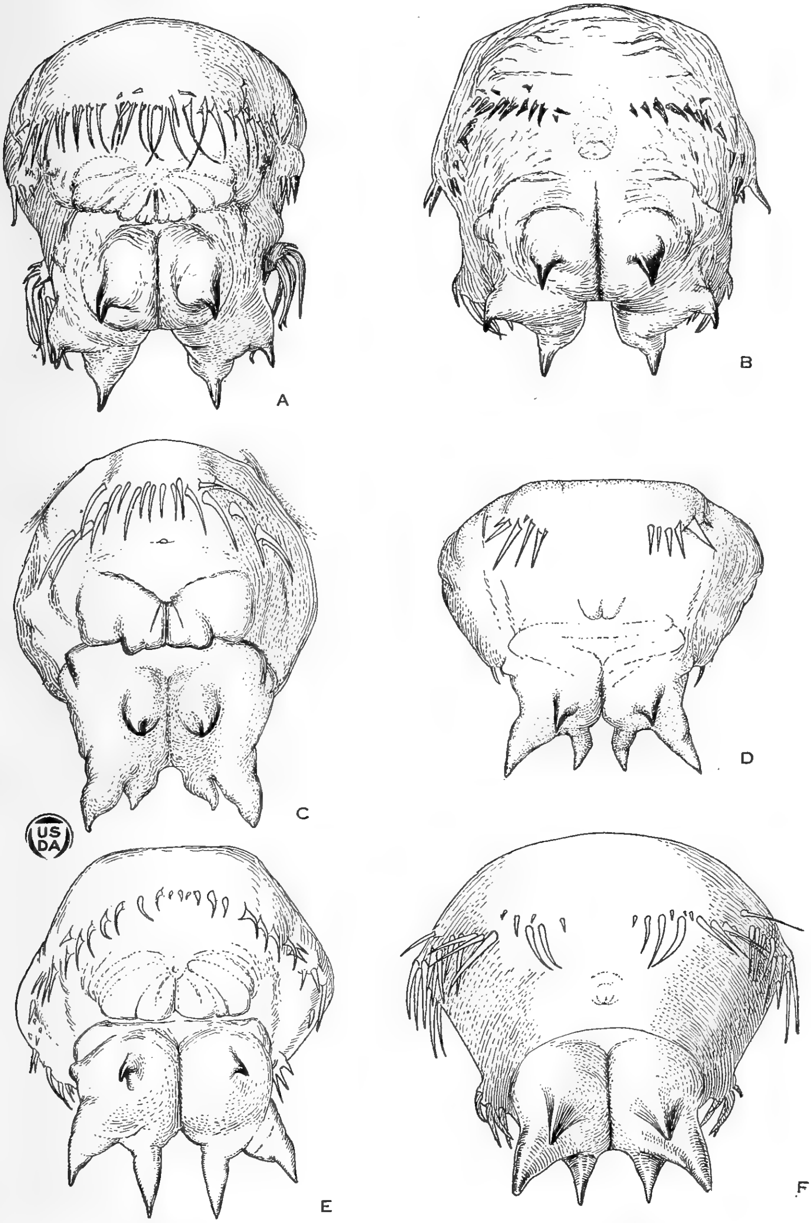


FIG. 14.—Ventral aspect of anal segment of pupa in several species of Tabanus: *A, Tabanus punctifer*, male; *B, T. punctifer*, female; *C, T. insuetus*, male; *D, T. insuetus*, female; *E, T. phaenops*, male; *F, T. monoensis*, female.

with the usual lines very faintly marked; the antealar callosity variable, reddish or dark. The black stripe inclosed between the reddish sides of the abdomen is generally rather broad, and somewhat expanded at the posterior

margins of segments 2 and 3, so as to appear jagged; the red on the sides of segments 2, 3, and 4 is clothed with a scarce and very minute golden-yellow pubescence, in the shape of faint, oblique spots; it also forms a fringe on the incisures.

T. phaenops is very like *T. sonomensis*, but it is usually a little smaller, the front is narrower, the bifurcation of the third vein is not clouded; in most, but not in all, specimens, the red on the sides of the abdomen is less extended, leaving a broader black stripe in the middle, which is expanded at the abdominal incisures, and therefore appears jagged. In shape, the abdomen is more elongated, with more parallel sides. In life, this species is easily distinguished by the color of its eyes, which are of a very bright green, with comparatively narrow purple cross-bands, much narrower than the green intervals between them; no purple in the upper and lower corners of the eye (at least, in the specimens observed).

Hab.—Webber Lake, Sierra County, Calif., July 27. Four females. Two specimens from Fort Bridger, Wyo., August 4, seem also to belong here.

Distribution.

Professor Hine (*3*) gives the distribution as "from Alaska and British Columbia to California, and specimens are also at hand from Wyoming and Colorado." In California it was found very abundant east of the Sierra Nevada Mountains as far south as near Bishop and as far north as Alturas. Specimens were taken north of Bishop, and at Bridgeport, Topaz, and Alturas, Calif. In Nevada the species is abundant near Deeth and at Wellington.

Abundance.

This is the most abundant horse-fly in Antelope Valley and at Bridgeport and Alturas, Calif. It is reported to be exceedingly abundant and a pest of great importance on the range north of Bishop, Calif. It is the most abundant species in Antelope Valley and at Deeth, Nev. In Antelope Valley these flies were more abundant in 1915 than during the four following years. They were fairly abundant in 1918, but comparatively scarce in 1919. The earliest seasonal appearance of the species was May 19, in 1918. As a rule they become gradually more abundant until the middle of July. They are abundant until the latter part of August, when usually there comes a marked reduction. They become gradually scarcer and few are seen after October 1. The latest seasonal activity observed was on October 19, in 1916. Only one specimen was observed. After the first of September, as a usual thing, they give very little trouble.

Habits of the Adult Female.

FEEDING HABITS.

Hosts attacked by *Tabanus phaenops* are horses, mules, and cattle. Occasionally one will attempt to feed upon man. They begin soon after sunrise and gradually increase in numbers until about 10.30 a. m. From then until 4 or 5 p. m. they are abundant. The horses and cattle congregate in separate bunches about 10.30 a. m. The horses continually fight the flies with mouth, feet, and tail, not venturing to feed at all until about 4 or 5 p. m.

When these insects attack, they bite mostly on the shoulders, neck, and face, around the breast, and below the elbow (fig. 15). The

painful part of the feeding process is the puncturing of the skin. The senior author permitted a hungry fly to bite him on the arm. She made several painful punctures before the blood meal was completed. When the beak is withdrawn a little blood usually flows out and coagulates upon the skin. Animals badly bitten have a rather bloody appearance. Unlike *T. punctifer*, when this species has punctured the skin it is not easily disturbed and can often be captured in the hand. Both males and females in captivity eagerly feed upon sweet substances. They were very fond of mint-flavored candy. Females in captivity could not be induced to bite a host. As discussed on page 34, this species was attracted to and fed upon a fresh beef hide, exposed bloody side out.

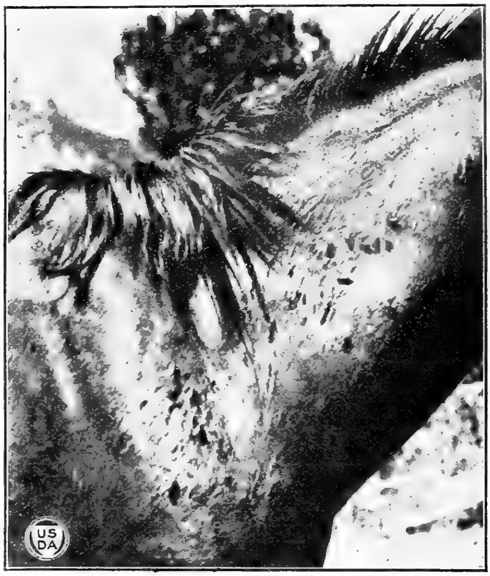


FIG. 15.—*Tabanus phaenops* feeding on a horse.

HABITS OF MALES AND MATING.

Males were rather abundant in grass near swampy areas. Several times males were observed to crawl down a grass stem or other object to the surface of water and drink.

Several matings were observed in August, 1919, in a pasture where the grass was about knee high and quite dry. About 8.30 on a warm, bright morning two flies were seen mating in air about 8 feet above the ground. They were flying rapidly and soon came to rest on a stem of grass, where they were captured, still attached. Between 8 and 9 o'clock on another day four flies were observed in the air apparently all clinging together. After about 10 seconds they separated and flew away. A few minutes later two were seen in the air, but they soon separated and disappeared. Another pair mating in the air came to rest on a stem of grass, remained for a minute and a half, then separated and flew away. One pair mating in air were interrupted by two other flies, apparently of the same species. None of these were captured. Observations did not reveal whether mating began in flight or at rest.

OVIPOSITION.

Egg masses were very hard to find in nature. After a long search a few masses were finally found on stems of grass or on dried stems from 2 to 4 inches above the ground in marshy places. In cages the egg masses were found on straws and on the under side of sheets of cork an inch or two above and overhanging the water.

EGG MASS.

The form of the egg mass of *Tabanus phaenops* varies in width and length with the width or diameter of the object to which it is attached. A mass attached to a flat piece of cork was 15.6 millimeters long and 5 millimeters wide. (Pl. II, *D*.) The egg mass tapers to very narrow ends. Specimens attached to slender stems are longer and more narrow. The mass is constructed of two layers, which are parallel to the object to which they are attached. The eggs slant at an angle of about 30°. The mass when laid is white. In a day or two it is dark gray, and before hatching is black. The number of eggs in the masses hatched varied from 180 to 305, the average being 290. The eggs are apparently not covered with cement and become detached rather easily.

INCUBATION PERIOD.

The egg of *Tabanus phaenops* measures 2 millimeters in length and 0.4 millimeter in width. The distal end, from which the larva emerges, tapers to a narrow diameter. The opposite end is narrowed on one side, giving the egg a rather flattened area where it is attached. The incubation period is given in Table 4.

TABLE 4.—*Incubation period of Tabanus phaenops.*

Date.	Egg mass No.							Temperature.		
	7661	7662	7666	7668	7673	7677	7692	Max.	Min.	Mean.
1918.								°*F.*	°*F.*	°*F.*
June 18	[1]	[1]						86	51	68.5
19								84	52	68.0
20								82	60	71.0
21			[1]					79	55	67.0
22								83	56	69.5
23								86	50	68.0
24				[1]				85	46	65.5
25								86	47	66.5
26	[2]	[2]						88	48	68.0
27			[2]		[1]			89	48	68.5
28								93	47	70.0
29								93	48	70.5
30				[2]				84	46	65.0
July 1						[1]		88	53	70.5
2								88	56	72.0
3					[2]			88	51	69.5
4								85	43	64.0
5								85	47	66.0
6								87	45	66.0
7								89	44	66.5
8						[2]		88	53	70.5
Aug. 3							[1]	87	45	66.0
4								88	42	65.0
5								87	33	60.0
6								86	35	60.5
7								80	38	59.0
8								83	37	60.0
9								84	43	63.5
10								85	43	64.0
11								84	42	63.0
12							[2]	87	37	62.0
Incubation period (in days)	8	8	6	6	6	7	9			
Average daily mean temperature	67.9° F.	67.9° F.	67.7° F.	68.1° F.	69.6° F.	67.8° F.	61.9° F.			

[1] Deposited. [2] Hatched.

The mean temperature on the day of oviposition was not figured in the average mean.

Larva.

Like *Tabanus punctifer*, the larva of *T. phaenops* is ready to molt upon hatching. The first exuvia are found soon after hatching in the water into which the larvæ have dropped.

DESCRIPTION OF THE FIRST EXUVIUM.

The length of the first exuvium is 2.4 millimeters. The first to seventh abdominal segments have an anterior margin of from 4 to 6 rows of spines. The neck of the first thoracic segment is armed with spines. Spines are lacking on the second and third thoracic segments. On each side of the venter, midway on each thoracic segment, is a tuft of two long and one or two short bristles, similar to the tufts on *T. punctifer*.

DESCRIPTION OF THE SECOND INSTAR.

The length of alcoholic specimens of *T. phacnops* is from 2.6 to 2.8 millimeters. The general color is white; alcoholic specimens become pale yellow. Every segment has fine longitudinal striations. The anterior end of the first thoracic segment has a collar of yellow pile covering about a fourth of the segment. Narrower margins of yellow pile encircle the anterior ends of the second and third thoracic segments. On each side of the venter midway on each thoracic segment is a tuft of three bristles similar to those in *T. punctifer* except that in *T. phaenops* the bristles are of approximately equal length. A few scattered bristles appear on each segment.

Each abdominal segment has the six-spined protuberance or prolegs and between these and continuing in a strip beyond them over the dorsum are spines slightly smaller. Around the middle of each abdominal segment are scattered bristles.

The anal segment is encircled anteriorly with yellow pile. The anus, broadly elliptical in shape, has a margin of yellow pile. The siphon, which is only half as long as the anal segment, has yellow pile around its folding anterior end. Around the opening of the siphon are numerous bristles.

DESCRIPTION OF FULL-GROWN LARVA.

The full-grown larva (fig. 16, *A;* Pl. II, *E*) is about 30 millimeters long. General color dirty gray, shading sometimes to greenish or reddish. Arrangement of propodia as in *T. punctifer.*

Prothorax: Anterior portion back of collar smooth and shiny on all aspects. Posteriorly, some striation shows on practically all aspects.

Mesothorax and metathorax: Upon each dorso-latero-cephalic area the brown of the anterior collar projects backward slightly, ending in a point.

Sides of all abdominal, and mesothoracic and metathoracic segments strongly striated. Siphon striated on all aspects. Dorsum of seventh and eighth segments fairly smooth and shiny (posterior part of eighth striated). All others striated with fine wavy lines between striæ; sixth less strongly and distinctly striated than those preceding it.

On ventral aspect of abdominal segments the striæ are broken up into irregular wavy lines, except for an area directly anterior to anus, which is smooth and shiny.

On venter of each thoracic segment are two distinct hairs placed one at each side and about midway between anterior and posterior margins of segment.

Anus surrounded by light brownish pile. Longest axis transverse. The siphon measures 0.5 millimeter.

The most characteristic features of the living larva are the dirty gray color, prominent prolegs, and strong striation of the sides of the abdominal segments, especially the anal segment.

Descriptions of larva made with the aid of a binocular microscope.

Habits of the Larva.

Larvæ of *Tabanus phaenops* hatched in a vial of water remain at the bottom of the water. The full grown larvæ of this species were

found mostly in swampy areas overgrown with grass, on or near the surface of the soil in masses of decaying vegetable matter. They were collected in the higher mountain valleys as well as in the floor of the lower valley. They were seldom found in the loose gravel by streams or in the loose humus where *T. punctifer* was so abundant around the shore of the lake.

PUPA.

(Fig. 14, *E*; Pl. II, *C*)

Length about 15 millimeters. Width of thorax 3 millimeters. Pale yellowish. Wedge-shaped teeth at anterior end not prominent. Palpal sheaths not prominent. Dorsum of prothorax smooth except for two slight rugosities, one at either side of the median line, slightly posterior to bases of palpal sheaths. Rima of thoracic spiracle broadly curved, not forming distinct hook.

Circlet of bristles on abdominal segments not double as in *Tabanus punctifer*. Dorso-lateral fringes on eighth segment normal. Ventral fringe on this segment continuous across median line. Of the terminal teeth on anal segment, the two lateral teeth are larger than the others, and these are arranged almost in a straight line with the two dorsal teeth.

Described from a single male specimen with the aid of a binocular microscope.

Table 5 contains the records of those individuals which were successfully reared from larva to adult in the laboratory.

TABLE 5.—*Pupal period of Tabanus phaenops.*

No.	Date of pupation.	Date of emergence.	Duration of pupal period.	Sex.
			Days.	
6873-1	June 2, 1917	June 25, 1917	23	Male.
6875-1	June 19, 1917	July 6, 1917	17	Female.
6884-8	July 15, 1918	July 30, 1918	15	Female.
6884-9	July 2, 1917	July 16, 1917	14	Male.
6884-12	Aug. 2, 1917	Aug. 19, 1917	17	Female.
6884-24	July 15, 1918	July 29, 1918	14	Female.
7505-1	July 15, 1918	July 29, 1918	14	Female.
8700-102	July 16, 1919	July 28, 1919	12	Male.

The average pupal period was 15.7 days. The complete life cycle was not determined. It is certain, however, that not more than one generation a year is produced.

TABANUS INSUETUS Osten Sacken.

DESCRIPTION OF ADULT

Tabanus insuetus is a small gray species with colored bands extending transversely across the eyes. (Pl. III, *A*, *B*.) Osten Sacken's description (*11*, *p. 219*) is as follows:

TABANUS INSUETUS n. sp.—Belongs apparently to the subgenus *Atylotus*. Eyes pubescent, although in the female specimens the pubescence is often hardly perceptible; in life, pale olive-green, with a single very narrow brown stripe in the middle (distinct even in dry specimens); no vestige of an ocellar tubercle; frontal callosity rather small, variable in size, narrower than the front; third antennal joint rather broad and short, with a short and stout annulate portion; palpi stout at base; first posterior cell broadly open; base of upper branch of third vein knee-shaped, in many specimens with a stump of a vein. All these characters would justify the location of the species in

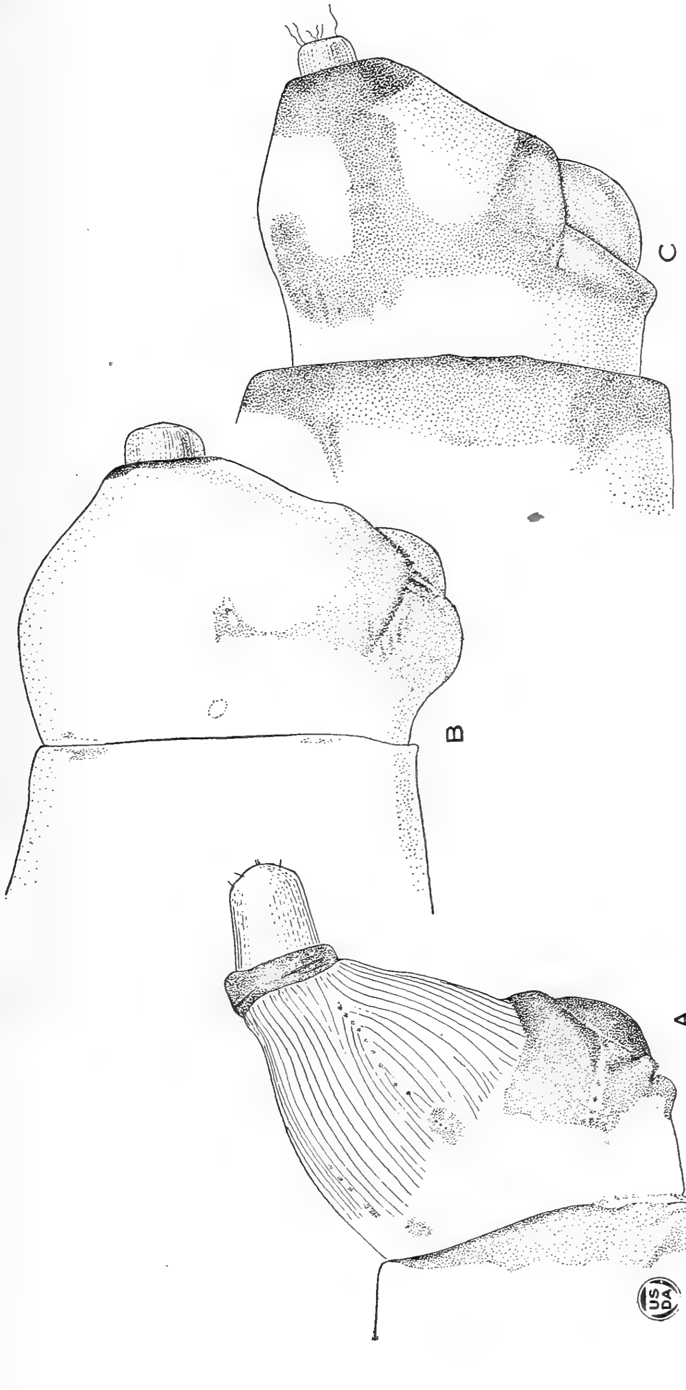


FIG. 16.—Anal segment of larva in three species of Tabanus: *A*, *Tabanus phaenops*; *B*, *T. insuetus*; *C*, *T. monoensis*.

that sub-genus; the discovery of the as yet unknown male will have to decide it.

Female.—Face and front yellowish-gray; cheeks with pale hairs; front with short black hairs; a fringe of such hairs on the upper edge of the occiput. Front broad (in most specimens; much narrower in others); frontal callosity narrower than the front, rather small, and variable in shape; usually another black, shining spot above it. Palpi short, stout at base, pale yellowish or yellowish-white, with black pile. Antennæ pale brownish-red; annulate portion of third joint sometimes, but not always, black or brown. The black ground-color of the thorax is partly concealed under a gray pollen; vestiges of longitudinal gray lines are visible anteriorly; a pale golden, sometimes whitish, appressed, rather scarce, pubescence, and black, erect pile clothe the dorsum. Pleuræ gray, with pale gray hairs. Abdomen in well-preserved specimens with three rows of yellowish-gray spots, formed by an appressed pubescence; the triangles of the intermediate row large, occupying the whole breadth of the segment; the spots of the lateral rows are oblique, prolonged laterally along the hind border of the segments (well-preserved specimens seem rarely to occur; in the worn specimens, the abdomen appears as grayish-black, somewhat reddish on the sides of the first two segments, and with but vestiges of the appressed yellowish-white pubescence and of the abdominal spots). Venter uniformly yellowish-gray. Feet variable in coloring, pale reddish-yellow with blackish (seldom pale) femora and tips of tibiæ; tarsi blackish with two posterior pairs paler at base. Costal cell and stigma more or less tinged with brownish-yellow; upper branch of third vein often, but not always, with a stump of a vein. Length 12—13 mm.

Hab.—Webber Lake, Sierra County, July 21. Twelve females.

Although not so conspicuous as either *T. punctifer* or *T. phaenops*, *T. insuetus* is a hard biter and occasionally becomes numerous enough in some of the higher mountain valleys to be troublesome to stock. It confines its attack for the most part to the legs and abdomen when attacking horses.

The larvæ are to be found without much difficulty in wet places in the upper valleys, in the top soil and humus at the base of grass roots. Abundant as the larvæ were in such situations, the eggs of this species have never been seen in nature, nor did the authors succeed in inducing ovipositions in rearing cages.

Quite a number of individuals of this species were reared from the larva to the adult stage in the laboratory. The pupal period was found to vary from 15 to 22 days.

Description of Full-Grown Larva.

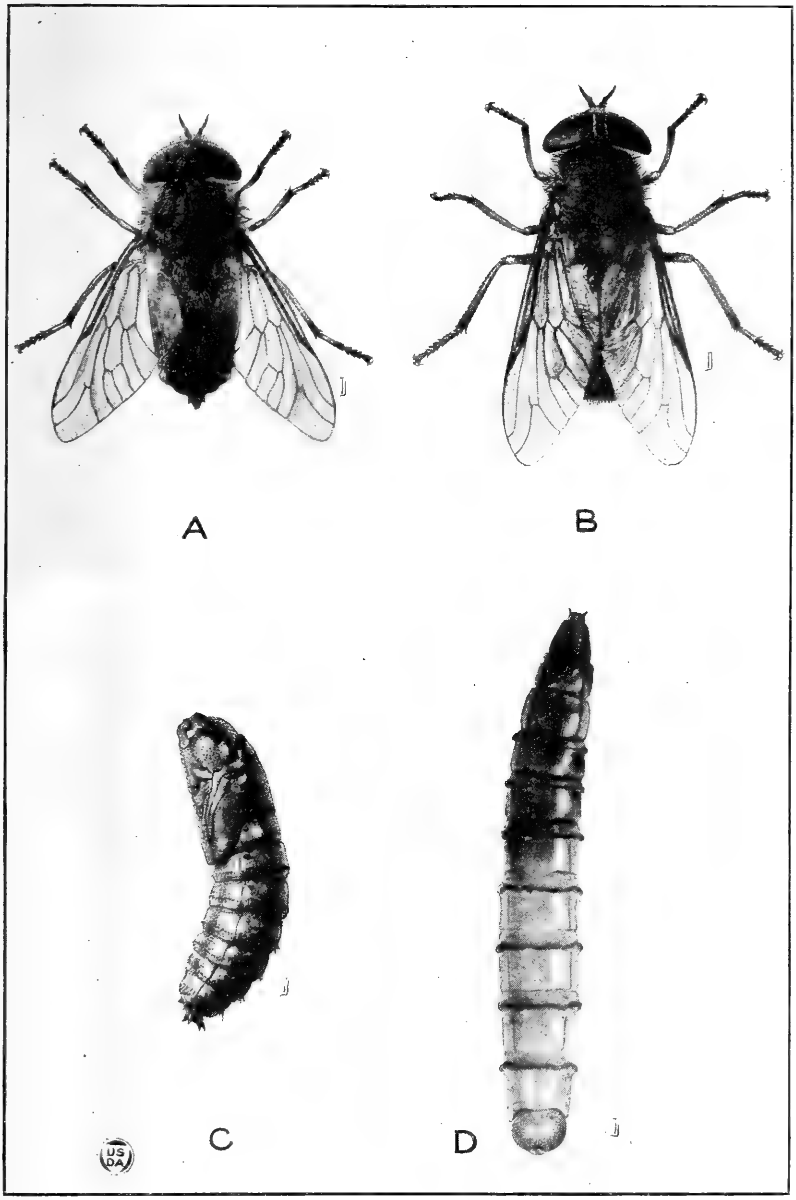
Full-grown larva (fig. 16, *B*; Pl. III, *D*) 21 to 22 millimeters long, yellowish white. Dorsal and ventral aspects of all thoracic and abdominal segments smooth and shiny. Sides of all segments, except prothorax, mesothorax, and anal segment, finely striate. On each lateral aspect of mesothorax are two deep longitudinal lines (not continuous on prothorax but showing more faintly on metathorax). Sides of prothorax smooth and shiny. Propodia arranged much the same as in *Tobanus punctifer*, not very prominent in living specimens, clothed with fine yellowish hairs which can hardly be called bristles.

Anal segment robust. Anus surrounded by an opaque surface, bearing fine yellowish pile. From each side of the anus extends dorsally a slight streak of opaque which divides just before reaching the dorsal surface into two branches, one extending posteriorly and the other dorso-anteriorly. Siphon very finely striated, extending barely beyond anal segment.

Description of Pupa.

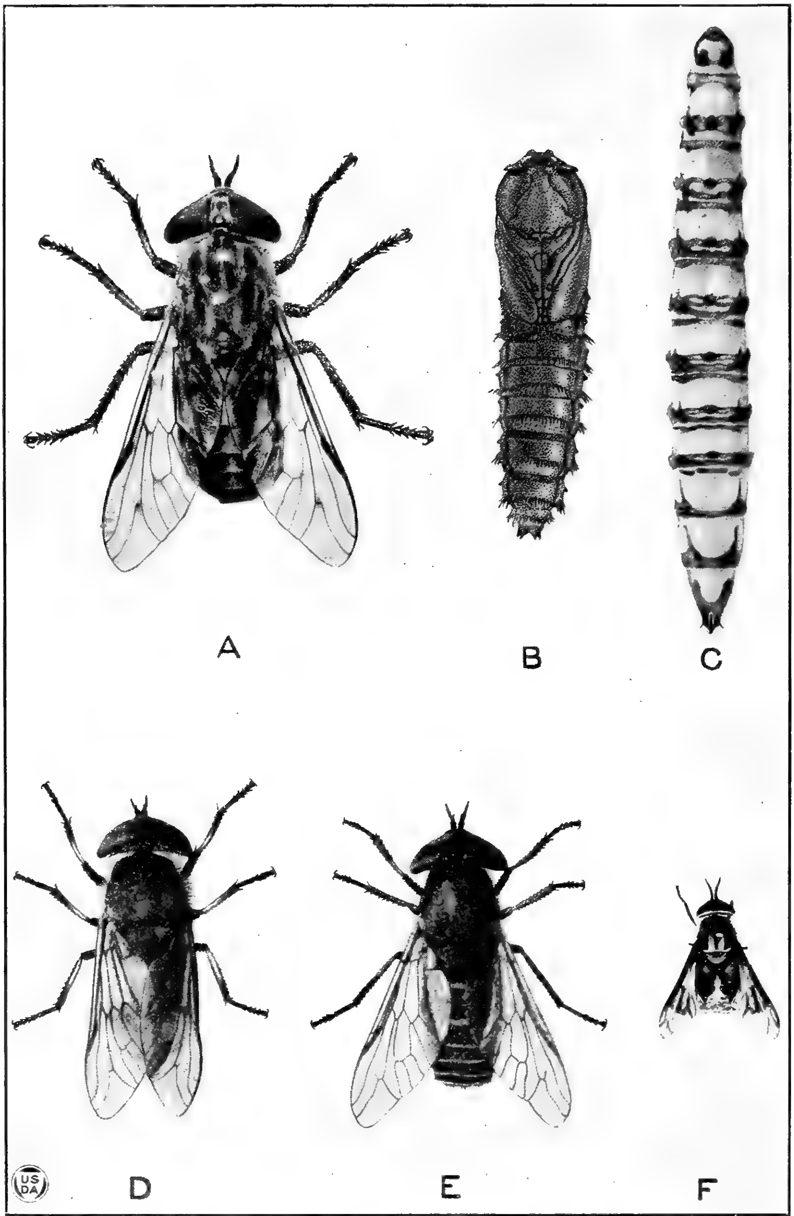
Pupa (fig. 14, *C*, *D*; Pl. III, *C*) 13 to 15.5 millimeters long. Width of thorax 2.5 to 3 millimeters. Color light yellow with brown spots on head and thorax.

Head region between bases of palpal sheaths rugose. Back of this two slightly elevated and rugose areas one at each side of median line. Still farther back



TABANUS INSUETUS.

A, adult male; *B*, adult female; *C*, pupa; *D*, full-grown larva.



TABANUS MONOENSIS N. SP., T. PRODUCTUS, AND CHRYSOPS COLORADENSIS.

A, *Tabanus monoensis*, adult female; *B*, pupa of same; *C*, larva of same; *D*, *Tabanus productus*, adult male; *E*, adult female of same; *F*, *Chrysops coloradensis*, adult female.

and more widely separated are two small tubercles. On ventral aspect posterior to palpal sheaths two small tubercles on each side which normally appear to bear a seta each.

In the male the rima of thoracic spiracle is curved into a hook at each end. In the female only the anterior end is hooked.

Abdominal segments 2 to 7 armed with a double circlet of bristles as in *Tabanus punctifer*, those on second segment very short. Bristles increasing in length up to seventh segment.

In the female the dorso-lateral fringe of bristles on the eighth segment just anterior to the terminal teeth is vestigial, and in the male entirely wanting. On the ventral aspect of this segment in the female the fringe of bristles is interrupted on the median line while in the male it is continuous. Of the terminal teeth the two lateral ones are most prominent. In the female the lateral teeth are arranged in a straight line with the two dorsal teeth. In the male the dorsal teeth point more directly upward.

Both larva and pupa were described with the aid of a binocular microscope.

A NEW SPECIES OF TABANUS.

A number of Tabanus larvæ collected in the mud along mountain rivulets were placed in breeding jars, and one or two adults were reared. These were found by Professor Hine to represent an undescribed species of Tabanus. (Pl. IV, *A*, *B*, *C*.) No adults of this species were found in Antelope Valley in the open.

Description of Adult.[6]

Tabanus monoensis n. sp.

Length 12 to 14 millimeters. Eyes not hairy, a small, four-sided, nearly denuded spot, narrowed anteriorly, on the frontal vertex. Wing with the furcation of the third vein and the transverse veins at the apex of the discal cell plainly margined with brown.

Female (Pl. IV, *A*): Front at vertex nearly one-third as wide as either eye, narrowed somewhat below, frontal callosity occupying the entire width of the front, shiny black, nearly square, and with a rather obscure connected line above reaching two-thirds of the distance to the vertex. Spot at vertex four-sided, plainly narrowed before, entirely separated from the eyes, very thinly pollinose and without any ocelligerous prominence such as is present in species of Tabanus with hairy eyes. Subcallus plainly pollinose but not so dense as the face. Palpi white, enlarged basally, pointed below, and clothed with black and white hair. Proboscis uniformly nearly black. Antenna brown, with the annulate portion of the third segment black, first segment prominently enlarged, nearly as wide anteriorly as the base of the third segment; second segment small, more or less hidden between the first and third; third segment widest at the base, with a small prominence dorsally, then gradually narrowing to the annulate portion of the segment, which is pointed at apex and distinctly shorter than the basal portion. Facets of the eyes of nearly uniform size throughout.

Thorax dark with gray stripes; wing hyaline with the furcation of the third vein and the transverse veins at the apex of the discal cell plainly margined with brown; some of the other veins, especially those having a transverse direction, very obscurely margined with the same color. Legs yellowish brown and black, all the femora black, front tibia yellowish brown on a little more than basal third, remainder black, middle and hind tibiæ largely yellowish brown, darkened apically, front feet black, other feet largely dark yellowish brown, darker above than beneath.

Abdomen dark in ground color with three rows of small gray spots. Hind margin of each segment narrowly gray also. Venter of abdomen partially reddish.

Male: Like the female in coloration. Compound eyes with small facets around the outside and a large area of enlarged facets on the disk. The dry specimen shows a conspicuous fuscous marking on the middle of each eye which takes the form of a somewhat irregular band across the head, widest at mid-

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[6] Description by James S. Hine.

dle and gradually narrowed at each end outwardly. The specimen of this sex is deformed and there is some question about the permanence of the characters presented.

Holotype female, No. 24950 U. S. National Museum. Reared at Topaz, Mono County, Calif., by Webb and Waite, and bearing the labels "Bishopp #7652, Br. 2," and "Bred July 10, 18."

Allotype (a deformed specimen) bearing the labels, "Bishopp #7652, Br. 1*a*" and "Topaz, Cal. 6–31–18." Also in U. S. National Museum.

Nine female paratypes collected and sent in by C. F. Baker and bearing the label "Mts. near Claremont, Cal. Baker," but without date of capture.

The paratypes show some variation from the holotype in having some red under the lateral spots of the abdomen and in the redder antennæ. On account of specimens being rubbed, the body is shinier and the subcallus in some specimens is more or less denuded. The venter of the abdomen is quite broadly red in some of the Claremont specimens.

The combination of characters in the diagnosis above will serve to locate this species easily. It suggests most perhaps some specimens of *T. nivosus* Osten Sacken, but the latter lacks the spot at the vertex, and the wing veins are not so plainly margined.

Description of Full-Grown Larva.[7]

Full-grown larva of *Tabanus monoensis* about 25.5 millimeters long. Color (fig. 16, *C;* Pl. IV, *C*) white with brown markings. Seen with the naked eye, the larva is white with three brown spots on the anterior margin of each abdominal segment except the anal, which has only two. The spots upon each segment are situated in a transverse row, one in center of margin of dorsum and one at each side on dorso-antero-lateral aspect. Under the binocular microscope these brown spots are seen to be merely accentuated parts of brown bands encircling the segments as in *T. punctifer.*

Prothorax with the five principal longitudinal grooves present as in other species, but faint and not extending to posterior margin. Sides opaque on anterior three-fourths. Back of opaque area finely striate to posterior margin. Pronotum smooth and shiny. Venter with a narrow median strip of opaque; smooth and shiny on each side of this strip. Mesothorax and metathorax smooth and shiny on notum and venter. Anterior margins banded all around with brown opaque which on each side slightly extends posteriorly in four longitudinal stripes.

Abdomen with prologs about the same as those of *T. punctifer.* Sides of segments finely striate. Dorsum of sixth and seventh segments striate; on preceding segments striation on dorsum is faint. Striation faint on venter of all segments except anal, which back of anus is striated all around. Anus surrounded by fine, pale yellowish pile, bordering which is a narrow circle of brown opaque, without pile. From each side of anus a rather broad band of brown opaque extends dorsad to margin of dorsum, where it spreads posteriorly and anteriorly. Posteriorly it continues at about the same width to siphon and passes entirely around this organ. Anteriorly it goes nearly to anterior margin of segment, then broadens out on dorsum into an irregular splotch of brown color. Siphon very finely striate and bearing at tip a few setæ.

Described from specimens collected by J. L. Webb under Bishopp No. 7652, near Topaz, Calif.

Description of Female Pupa.

Length of pupa (fig. 14, *F;* Pl. IV, *B*) about 16 millimeters. Width of thorax 3 millimeters. Color yellowish brown. Tubercles on head and thorax as in *Tabanus punctifer,* though less prominent. In the one (reared) specimen available, which was probably nearly ready to transform when killed, the eyes show almost black through the skin and there are brown spots on the thorax.

Rima of thoracic spiracle curved into a small hook at anterior end.

Double circlet of bristles beginning on second abdominal segment and becoming progressively longer on succeeding segments up to the seventh. Dorso-

[7] Description of larva and pupa by J. L. Webb.

lateral fringe of bristles on anal segment normal. Ventral fringe on this segment interrupted on median line. Terminal teeth on anal segment nearly equidistant. Lateral teeth only slightly more prominent than the others.

Described from reared specimen under Bishopp No. 7652, Br. 2, larva of which was collected by J. L. Webb near Topaz, Calif.

Both larva and pupa described with the aid of a binocular microscope.

CHRYSOPS spp.

Two or three specimens of the genus Chrysops, known commonly as deer flies, are common in the region covered by this investigation. (Pl. IV, *F*.) They are, however, less important as pests than true horse-flies of the genus Tabanus. They attack horses and men quite readily in the higher altitudes, but do not appear to bother cattle to any great extent.

The eggs and larvæ are rather abundant in Antelope Valley, but for some unexplained reason adults are not found there in the same proportions. Eggs are deposited on vegetation above the water, or sometimes on the leaves of a water plant which lie flat on the water. The larvæ are to be found in the mud under the water.

NATURAL ENEMIES OF TABANIDS.

PARASITES.

Hymenopterous parasites reared from egg masses of *Tabanus punctifer* were identified as *Prophanurus emersoni* Girault.[8] Practically every *T. punctifer* egg mass collected was infested. This little parasite was observed crawling over a mass of *T. punctifer* eggs before the parent female had completed the oviposition.

The total developmental period of this parasite was determined in three masses.

TABLE 6.—*Developmental period of Prophanurus emersoni.*

Tabanid egg-mass No.	Date of oviposition of tabanid and parasite eggs.	Date uninfested tabanid eggs hatched.	Date parasites began to emerge.	Incubation period of host.	Developmental period of parasite.
				Days.	*Days.*
4693. Br. 1	Aug. 9	Aug. 23	Sept. 1	14	23
7694. Br. 1	9	20	Aug. 31	11	22
7694. Br. 2	9	23	Sept. 1	14	23

Egg mass No. 7694 Br. 1, from August 16 to August 20, was in direct sunlight out of doors. This shortened the incubation period of *T. punctifer* 3 days and the developmental period of the parasite only 1 day.

Males of this parasite would congregate around the holes from which the females were to emerge, and when the female emerged mating took place immediately.

The few egg masses of *T. phaenops* found in nature were not infested. An egg mass of *T. phaenops* was infested with *Prophanurus emersoni* in captivity. On August 5, 1918, an egg mass

[8] Determination by S. A. Rohwer.

of *T. phaenops* deposited August 3 was placed in a vial containing some hatched egg masses of *T. punctifer* on which were freshly emerged parasites. On August 9 the egg mass of *T. phaenops* was again isolated and from it on August 12 hatched 186 Tabanus larvæ. On August 27 one of the unhatched eggs was opened and a pupa of a parasite was found. Several adults of the parasites emerged August 29. Thus while eggs of *T. phaenops* are not known to be infested with any parasite in nature, this parasite was successfully reared from it in captivity.

Transportation of Parasites.

This same parasite, *Prophanurus emersoni*, was previously reared by D. C. Parman at Uvalde, Tex., from egg masses of *Tabanus hyalinipennis* Hine. On account of its abundance and the abundance of the host eggs in that locality in Texas, it was considered wise to attempt the transportation of the species from Texas to Nevada and California. A few masses of infested eggs were mailed from Uvalde, Tex., on June 25. On July 2, at Topaz, Calif., these masses from which parasites were already emerging were placed in a vial with an egg mass of *T. phaenops* deposited July 1. On July 6 the eggs of *T. phaenops* seemed to be somewhat shrunken. On July 8 the egg mass was isolated. On July 22 some of the eggs of *T. phaenops* had hatched. On September 16 five parasites had emerged and were found dead in the vial. The antennæ of another dead one were protruding through an emergence hole in the leaf to which the mass was attached.

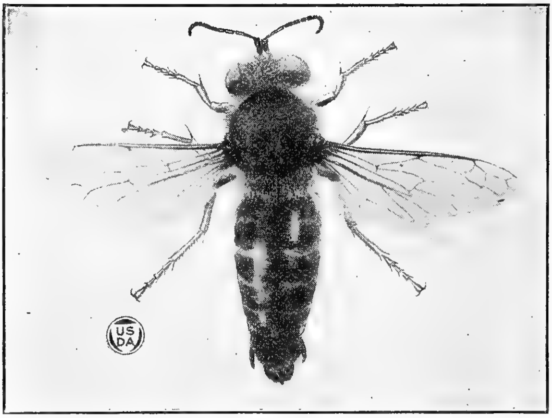

FIG. 17.—*Bembex primaaestate*, a predator upon horse-flies.

There can be little doubt that the activity of *Prophanurus emersoni* is a very important factor in the control of *Tabanus punctifer*.

PREDATORS.

Bembex primaaestate Johnson & Rohwer (fig. 17) is an insect similar to the "horse guard," *Monedula carolina* Drury. Hine (4) has given an account of the habits of the latter in Louisiana, and believes it to be an important enemy of horse-flies.

Residents in Antelope Valley had frequently observed the capture of horse-flies by wasps. In September, 1916, the senior author observed one pursuing a tabanid. A few minutes later one of these wasps was captured. It was identified as *Bembex primaaestate*. On July 19, 1917, a nest of this species was found in sandy gravel.

Digging with a shovel about the entrance to the tunnel, larvæ, cocoons, and a few adults of the species were found about a foot below the surface. Recently formed cocoons always had a mass of Tabanus fragments and in some cases fragments of other flies sticking to them. In the nest was also found a perfect male specimen of *Tabanus insuetus* and a perfect male *T. phaenops.* The predator, judging from reports of residents, is not annually abundant. It was rather scarce in 1916 and quite abundant in 1917. It is an interesting fact that in 1916 tabanids were more abundant than in 1917. Because of a scarcity of *T. phaenops* in the midsummer of 1917, it was believed that this predator, on account of its abundance that season, was a very effective check to the species. Bembex did not occur and *T. phaenops* was quite abundant in Bridgeport Valley 40 miles southwest and at a higher elevation.

It was decided to attempt transportation of Bembex from Antelope Valley to Bridgeport Valley. With nets 50 adults of the wasp were captured on July 23, 1917, and placed alive in two small cages about a foot square with bottoms covered with sand and gravel. In these cages they were taken hurriedly by automobile to Bridgeport Valley. About 35 survived the trip and were released at a place resembling the breeding places in Antelope Valley. Seven or eight cocoons of the species collected July 19 were placed there in gravel at the same time. Sufficient observations were not made there the following season to determine the result. In 1918 and 1919 the wasps were very scarce in Antelope Valley.

A close observation was made in 1919 of an attack on a female *Tabanus phaenops* by one of these wasps. The fly was feeding on a horse near the shoulder. Suddenly the wasp swooped down on the fly, grasped and stung her, and flew away, leaving the fly in feeding position. The fly was immediately paralyzed, so that she did not withdraw her mouthparts from the host. Her legs seemed no longer to grasp the hair of the horse and she was suspended by her mouthparts only. Removed from the horse, she seemed lifeless, except for a few quiverings of the legs. The wasp was seen no more. Undoubtedly this predator accomplishes considerable repression of the horse-flies, but in view of the data in hand can not be considered a major factor.

Stomachs of several species of insectivorous birds were examined without finding larvæ or adults of Tabanidae, a result probably not representative, since the Biological Survey has found horse-flies or their larvæ in the stomachs of no fewer than 78 species of birds.

PROTECTION OF ANIMALS.

Horses and cattle in pasture or on the range get some mutual protection from the flies by congregating so that switching of tails will brush their shoulders and heads. As previously mentioned, however, injuries result from kicking and hooking. Shade of trees, shade of buildings, and open sheds offer very little protection. It is a common observation, however, that *Tabanus phaenops* does not follow animals into the higher and drier arid lands. Stock in open range get much relief by going to sagebrush areas during the heat of the day.

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The species of tabanids in Antelope Valley do not enter stables. Many individuals of *T. phaenops* and *T. intensivus* entered and remained on the walls of a tent in Slinkard Valley, and occasionally *T. phaenops* would be seen on the screen of the laboratory at Topaz, but there is no record of any tabanids in Antelope Valley biting a host within a closed building.

Horses in harness, especially those worked around the swamps or in the hayfields, are greatly harassed by the flies. The parts of the body most in need of protection are the head and neck, where *T. phaenops* prefers to bite. For this is used a hood of burlap or light canvas with holes cut for the eyes, ears, and nostrils. The cape of it extends over the neck to the shoulders (fig. 18). Often nets or burlap coverings are used over the back and rump, more especially for protection against *T. punctifer*.

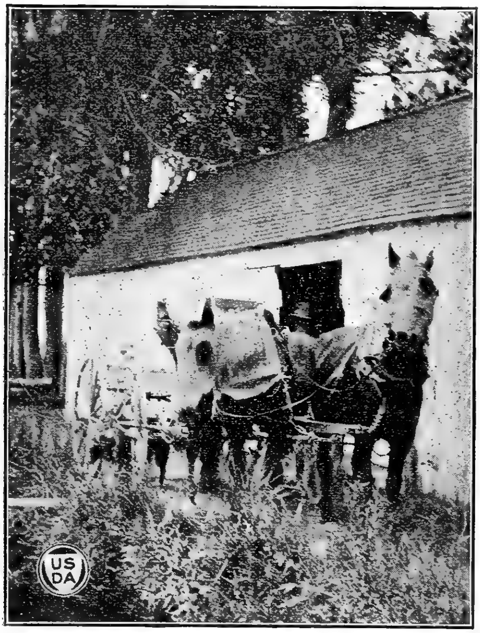

FIG. 18.—Horse hoods used to protect the head and neck of the animals from horse-flies.

REPELLENTS.

Several repellents were tested, but none of them gave any marked protection. Tabanids are very determined biters, and repellents applied frequently enough to give any protection have a harmful effect on the hair and skin of the animal.

REPRESSIVE MEASURES.

POISONING TABANIDS.

While collecting tabanids on June 23, 1917, at a sheep camp in Slinkard Valley, attention was drawn to the hide of a sheep killed on the previous day. The pelt was hung to dry with the bloody side out and many tabanids were on it. *Tabanus intensivus* was most abundant. *T. insuetus* was next in abundance.

On July 6, a fresh beef hide was hung over a fence at Topaz, bloody side out, and the following solution was applied to it:

Arsenite of soda	pound	$\frac{1}{4}$
Sugar	pounds	$2\frac{1}{2}$
Tartaric acid	teaspoonful	$\frac{1}{2}$
Water	gallons	$1\frac{1}{2}$

The hide was exposed from 10.30 a. m. to 5 p. m. No dead tabanids were found, although as many as one-half dozen flies of *T. phaenops* were seen on it at one time. Only three or four dead flies

of other species were seen. Two tabanids which ate some of the solution in the laboratory died immediately.

Poisoning tabanids by this method would be expensive and of little value.

A trap baited with bananas and set for several days caught only two females of *T. phaenops.*

No bait was found which would attract any great number of these flies into a trap. None of the species of tabanids in this region appear to congregate on buildings, as has been observed in the case of certain other species, notably in southern Florida and Louisiana. The chances of successfully trapping the species under discussion therefore seem to be very remote.

DRAINAGE.

It was ascertained that a large majority of *Tabanus phaenops* breed in areas which by drainage, not inconsistent with good agriculture, could be rendered unfit for tabanid development. Much time was spent in 1919 in determining whether tabanid larvæ were breeding in irrigated fields which drain readily or in irrigation ditches supplying them with water. No tabanid larvæ were found in well-drained fields, although earthworms were quite abundant. A few larvæ of *T. punctifer* were found in a gravel bank of a main irrigation ditch through which water flows nearly all the year. The principal land and cattle company in Antelope Vally was making plans and estimates for an extensive ditch drainage system which would drain many of the swampy areas of the valley. Such a system when completed and put into operation will render thousands of acres more productive as well as greatly relieve the tabanid situation. It can not be hoped that the drainage of the floor of the valley will eradicate tabanids, because there are springs and small streams in the foothills and higher up in the mountains which will provide limited breeding places. Of course Alkali Lake in the north end of the valley will also provide breeding places for *T. punctifer* in some numbers. It is firmly believed, however, that drainage will accomplish the ultimate control of the tabanid pest.

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DEPARTMENT BULLETIN No. 1222

Washington, D. C. ▼ March 14, 1924

GROWTH AND FEEDING OF HONEYBEE LARVAE

By

JAMES A. NELSON, formerly Expert in Apiculture
ARNOLD P. STURTEVANT, Apicultural Assistant
and
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CONTENTS

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GROWTH AND FEEDING OF HONEYBEE LARVAE.

By JAMES A. NELSON, *Formerly Expert in Apiculture*, ARNOLD P. STURTEVANT, *Apicultural Assistant*, and BRUCE LINEBURG, *Formerly Assistant in Beekeeping, Bureau of Entomology.*

PART I. THE RATE OF GROWTH OF THE HONEYBEE LARVA.

CONTENTS.

INTRODUCTION.

Notwithstanding the abundant literature on the adult honeybee, there is a relatively small amount of exact information concerning the life history of the larva, particularly with regard to the extraordinary rate of development and the factors influencing this growth. Straus (*9*),[1] in connection with a study of the chemical composition of honeybee larvæ at different ages, gives a series of careful weighings of larvæ at successive age periods 24 hours apart.

[1] Reference is made by number (*italic*) to "Literature cited," p. 24.

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His paper, however, discusses mainly the results of metabolism in relation to age, as determined by chemical analyses of the larvæ. The observations were made under environmental conditions which were probably somewhat different from those found in this country, and, although similar, the data can be only relatively comparable to those obtained in this country. Part of Straus's data are used in Table 2 and Figure 2.

The following data and observations are presented to clear up certain points about which there is need of information and deal especially with the rate of growth of the larva, which not only is of interest from a scientific point of view but also is of value to the breeder of queen bees. Observations concerning some additional factors influencing the rate of growth of the larva, as well as information concerning the time of change in the composition of the larval food, are also given.

Part of the work herein recorded, referred to under lots 1 to 7, was done during the years 1915 and 1916 by the senior author. This early work was done independently of the work of Straus (*9*). The observations referred to under lot 8 were made mainly during August and part of September, 1922, by the junior author independently, and are supplementary to the earlier work. In connection with these observations and some made during the same summer by Mr. Lineburg, which are described by him in Part II of this bulletin, further observations were made on the amount and nature of the larval food in relation to the rate of growth. These latter were made by the junior author assisted by Mr. Lineburg.

METHODS, LOTS 1 TO 7.

Recently hatched larvæ were selected by examination, and the cells containing them were marked with a quickly-drying paint, solutions of anilin stains in alcohol being found good for such temporary use. The comb containing these larvæ was removed at fixed intervals, larvæ of known ages were removed and weighed in carefully balanced watch crystals, and in case there was any adhering larval food this was first washed off and the larva dried. While the method of choosing larvæ according to their apparent age is open to objection, it is believed that errors arising from this source are insignificant, especially in the case of larvæ chosen from new comb, as in the case of lot 1. Toward the close of the experiments another method was used which promises to give more accurate results. Newly hatched larvæ are quite uniform in size and are flexed in an arc corresponding roughly to a semicircle having a diameter of about 1 millimeter. Eyepiece micrometers were constructed having in the center of each a circle of wire with an inside diameter of 1.10 millimeters. The appearance of the newly hatched larva with respect to the wire circle is shown in Figure 1. This method, when used with a binocular microscope with extensible arm, permits an accurate selection of larvæ of minimum size.

OBSERVATIONS, LOTS 1 TO 7.

WEIGHT OF EGGS.

On July 10, 1915, 10 eggs about ready to hatch were removed and weighed, the total weight being 0.8 milligram, average 0.08 milligram.

On July 12, 20 eggs from the same colony, proving on microscopic examination to be only a few hours old, weighed 2.65 milligrams, average 0.132 milligram. On July 13, 20 eggs from the same frame weighed 2 milligrams, average 0.1 milligram. On July 27, 1916, 20 eggs taken at random, and found on examination to be in different stages of development, weighed 2.3 milligrams, average 0.115 milligram. Since newly hatched larvæ weigh about 0.1 milligram, this may be taken as the average weight of eggs about to hatch, earlier stages being somewhat heavier.

RATE OF GROWTH OF LARVÆ.

Data regarding the rate of growth were secured in 1915 and 1916 for seven lots, five of these representing weighings made at 24-hour intervals (Table 1). The histories of these lots were as follows:

Lot 1 (July 14, 1915).—Ten larvæ of fairly uniform size from a single frame, surrounded by larval jelly which covered one-third to one-half of the bottom of their respective cells, were found to weigh exactly 1 milligram, and may therefore be considered newly hatched. About 50 cells containing such larvæ, all on the same side of the frame, were marked. Weighings were thereafter made at 24-hour intervals, 10 larvæ taken at random being included in the first two weighings and 5 in each of the three succeeding. The weights of this and other lots are given in Table 1. On the third day there was evident a noticeable difference in the size of the larvæ, one being appreciably larger than the others. This individual weighed 25.3 milligrams, the average weight of the other four being only 12.75 milligrams. When seen curled up in their cells, larvæ of this age occupy from 60 to 75 per cent of the diameter of the bottom of the cells. On the fourth day the weight of the smallest of the five larvæ was 50 milligrams; that of the largest, 89.5 milligrams. The larvæ at this time filled the bottom of the cells snugly and there was no trace of larval jelly. On the fifth day the two largest in the lot of five weighed together 328.15 milligrams, an average of 164.07 milligrams. The remaining three together weighed 450 milligrams, an average of 150 milligrams. Two of the five were sealed, two not sealed, and one partly sealed.

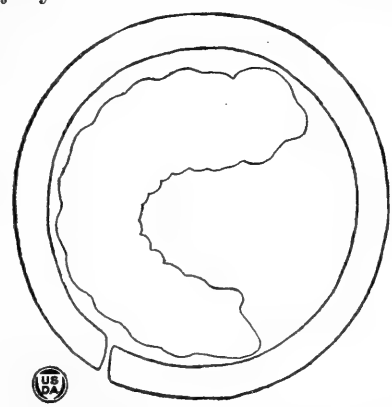

FIG. 1.—Outline sketch of newly hatched honeybee larva, as seen through the microscope in conjunction with an eyepiece micrometer composed of a fine wire ring, having an inside diameter of 1.1 millimeters.

Lot 2 (June 28, 1916).—A number of cells on a single frame containing larvæ chosen as newly hatched were marked. On June 29, 10 larvæ weighed 10.2 milligrams, or 1 milligram each, which is more than twice the weight of the larvæ of the same assumed age in Lot 1. This of course means either that the larvæ originally selected were too old or that the rate of growth during the first day was more rapid in this case. This difference continues up to the

time of sealing, so that it seems probable that these figures are somewhat too high throughout. At the second weighing (June 30) the larvæ were seen to differ greatly in size, ranging from 2.3 milligrams to 14.3 milligrams. The largest in the lot was some distance from the margin of the frame near a patch of brood about 4 days old. On July 1, larvæ 3 days old also displayed great differences in size. Three larvæ from the end of the frame, close to the brood-nest, were larger than the other two and weighed 54.4+ milligrams each. The two smaller, from the lower edge of the frame, weighed only 12.6 milligrams each. These smaller larvæ were still being fed larval jelly, while the three larger ones were being fed honey and pollen. On July 2, great differences in size were still evident, even between larvæ in adjacent cells. Two larvæ were beginning to be capped, one of these weighing 164.1 milligrams. The smallest larva in the lot weighed only 77 milligrams. On July 3, all larvæ of this lot were capped except one, which was partly capped. Capped larvæ of this and the three succeeding lots were not weighed. Weighings of 15 mature larvæ from this colony during the same season gave a total weight of 2,374.7 milligrams and an average of 158.31 milligrams.

For comparison in the table these weights are used for larvæ 4½ to 5 days old for Lots 2 to 4, and for larvæ 5½ to 6 days old for Lot 5.

Lot 3 (June 29).—About 40 cells containing newly hatched larvæ were selected from the same frame as Lot 2. At the first weighing (June 30) the larvæ appear quite uniform in size. At the second weighing (July 1) the weights ranged from 3.3 to 15.5 milligrams, and at the third weighing from 13.1 to 30.3 milligrams. On July 3, some cells of this series were completely sealed, one or two were partly sealed, but most of them were still open. Near the bottom of the frame there were three cells of this lot in a row; the two end cells were sealed, while the middle one was still open. The two sealed larvæ weighed 158.5 milligrams each; the one in the open cell weighed 117 milligrams. Another larva from an open cell weighed only 90.5 milligrams while a fifth weighed 114.3 milligrams. All the cells in this lot were sealed on July 4.

Lot 4 (July 5).—About 50 cells on the same frame were marked, great care being taken to mark only those cells containing larvæ of minimum size. On July 6, 5 larvæ weighed 3.05 milligrams, an average of 0.61 milligram. On the opposite side of the frame near a patch of brood were much larger larvæ belonging to this lot, one of the largest of these weighing 2.2 milligrams. On July 7 the larvæ in marked cells continued to show considerable differences in size. The larvæ of the group isolated among cells containing eggs remained smaller than those on the opposite side of the comb, located next to older larvæ. Most of the larvæ at this time covered a circle one-half to two-thirds of the diameter of the bottom of the cell. The total weight of five larvæ taken at random from both sides of the comb was 31.75 milligrams, an average of 6.35 milligrams. The individual weights, in milligrams, were as follows: 2.85, 3.7, 3.7, 9.55, 11.95. All larvæ were still fed with larval jelly. On July 8, the weights of 5 larvæ ranged from 17.5 to 55.3 milligrams. The larger were uniformily near unsealed brood, the smaller among eggs near the middle of the frame. The smaller larvæ occupied less than

two-thirds of the diameter of the bottom of the cells; the larger snugly filled the bases of the cells. On July 9 the weight of 5 larvæ was 502.7 milligrams or 100.54 milligrams each, the larvæ near brood continuing to exceed in size those on the opposite side of the frame. The mouths of the cells containing the two largest larvæ in this lot were beginning to be contracted. The weight of these two larvæ was 284.9 milligrams or 142.45 milligrams each. The two smallest larvæ in this weighing weighed 121.5 milligrams, or 60.75 milligrams each.

Lot 5 (July 6).—A new comb in the same colony was found to be full of eggs and young brood. About 60 cells on one side of the comb were marked, only the very youngest and most minute larvæ being chosen. Some of the larvæ were so recently hatched that they had not yet been supplied with food. The first weighing of 10 larvæ at the age of 1 day showed an average of 0.52 milligram. This is lower than the average weight for the same (estimated) age of any of the previous lots, except Lot 1. None of these larvæ were near older unsealed brood. On July 8 the average weight, 2.96 milligrams, approximated that of Lot 1 of the corresponding age, the individual weights ranging from 2.12 to 3.75 milligrams. On July 9 considerable differences in size appeared. The average, 14 milligrams, is close to that for the corresponding age in Lot 1, but a considerable range in size became evident—8.75 to 22.15 milligrams. The larvæ at this time covered a circle whose diameter is one-half to three-fourths that of the bottom of the cell. On July 10, the total weight of 5 larvæ was 295.2 milligrams, the individual weights ranging from 41.8 to 78.5 milligrams. On July 10 about 15 marked cells which contained larvæ remained; 3 of these were completely sealed, 2 one-half sealed, and 4 just beginning to be sealed. Weights were as follows:

	Milligrams.
1 larva completely sealed	171.3
1 larva one-half sealed	154.5
1 larva less than one-half sealed	151.7
1 larva with edge of cell slightly turned in	126.8
1 larva with edge of cell slightly turned in	128.6
Total weight	732.9
Average weight	146.6

Lot 6.—Fifteen to twenty larvæ from the same frame were selected as follows: The end of a wire 1 millimeter in diameter was ground off square, to be used as a measure, and only those larvæ were selected which in their normal position in the cell could be completely covered by the end of the wire. Such larvæ were approximately newly hatched. On the third day, larvæ were found in only five marked cells. These averaged 26.1 milligrams. The individual weights in milligrams were as follows: 14, 17.8, 19.3, 36.9, 42.5.

Lot 7.—On July 20 at 9.15 a. m., the queen in the same colony was placed in the center of the hive on a frame free from brood in a space partitioned off from the remainder of the colony by queen-excluding zinc. At 11.15 a. m. some eggs were found on the frame and the queen was removed, great care being taken to prevent her from returning to this comb. The hive was then closed and left undisturbed for three days. On July 23, at 3 p. m., this comb was examined under a binocular microscope and several larvæ were seen

surrounded by food. All seemed large as measured by the eyepiece micrometer. One unhatched egg was seen. According to previous observations of the writer, these eggs should have hatched between 11.15 a. m. and 1.15 p. m. on this date. On July 26, 5 of the 13 larvæ present were weighed, the individual weights in milligrams being as followed: 5.05, 6.1, 20.9, 23.4, 28.9. Considerable differences in the size of the larvæ were evident on examination of the comb. Three of the larvæ covered an area of less than one-half of the diameter of the bottoms of their respective cells, but most of them nearly or quite filled the bottoms of the cells. All of the larvæ were supplied with an excess of larval food.

VARIATIONS IN RATE OF GROWTH.

An outstanding feature of these observations is the great individual variation in the daily rate of growth as manifested in the differences between the weights of the 5 to 10 larvæ of the same age in different lots, as well as in the differences between individuals of the same age in the same lot. These considerable differences naturally led to the suspicion that they might have been due to the method used in selecting newly hatched larvæ. The experiment described under Lot 7 was intended to test this supposition. As already stated, larvæ 3 days old, hatched from eggs laid within a determined 3-hour period, showed wide divergences in individual weight. There were on hand two series of larvæ, each from a single batch of eggs laid within a known period of 2 hours, preserved in alcohol. The greater part of these were fixed in their cells, the earlier stages being embedded in the coagulated larval food and therefore unsuitable for weighing. Five larvæ 3 days old of one lot were free from foreign material and suitable for weighing for comparison with one another. These showed on superficial examination considerable differences in size. These larvæ were weighed separately, the weights in milligrams being as follows: 5.7, 7.35, 7.5, 9.8, 10.4. Although the differences in weight between the different individuals of this lot are not as great as between those of most of the other lots, still they are considerable, the difference between the smallest and the largest amounting to nearly 100 per cent. This result, taken in conjunction with the great differences between larvæ of the same age in different lots, makes it reasonable to conclude that considerable differences exist in the rate of growth of bee larvæ.

In fly larvæ Herms (*2*) determined that "there is an optimum when enough nourishment has been taken to pass through the metamorphosis to the best advantage." This optimum is evidently represented in the honeybee by a weight of about 158.31 milligrams when the larvæ are sealed by the worker bees. As far as the preceding observations on the honeybee are concerned, the optimum weight virtually coincides with the average weight at maturity.

LENGTH OF THE LARVAL PERIOD.

As the data show, sealing may begin as early as the end of the fourth day after hatching (Lots 2 and 3) and as late as the middle of the fifth day (Lots 1 and 5), the average for the five lots being about 4½ days (Table 1). It is noteworthy that a difference of half a day may exist between two lots from the same hive, not only during

the same season but with approximately the same weather conditions. In the case of two earlier lots from eggs of known age, not here recorded in detail, the larvæ were sealed between 5 and 5½ days, the sealing beginning when the larvæ were about 5 days old and continuing for some hours.

The individual differences in the time of sealing are well illustrated by the larvæ of one of these lots. These were all of equal age (within 2 hours), located on the same comb and therefore presumably subject to approximately identical environmental conditions. When the larvæ were approximately 5 days old, there were 43 larvæ on one side of the comb. Six of these were already sealed, while about half of the remainder showed a thin rim of wax around the mouths of the cells, indicating that capping had just commenced. Two and a quarter hours later about one-fourth of those cells open previously were sealed. At this rate it would require from 8 to 10 hours additional for the sealing of all cells to be completed. Such differences are typical of all the lots.

The data given for Lot 5 suggested that the sealing of the cell is commenced before the larva has attained maturity. To test this conclusion additional weighings were made from the same colony as follows:

	Milligrams.
4 larvæ from cells whose edges were just beginning to show signs of capping averaged	137.60
5 larvæ in which sealing was slightly more advanced averaged	142.20
10 larvæ from cells one-fourth to one-third sealed averaged	141.00
10 larvæ from cells one-third to one-half sealed averaged	158.21
10 larvæ from cells over one-half sealed averaged	157.20
15 larvæ from freshly sealed cells averaged	158.31

These figures show clearly that the sealing of the cell is actually commenced when the larva lacks about 20 milligrams of its final weight, and that the larva is fed until the cap covers about one-third of the mouth of the cell, at which time the larva attains its maximum weight. The completion of the cap probably occupies only a short space of time. The weight of mature larvæ is also shown to be quite constant, at least for a given colony at the same season of the year. Only one marked divergence from the average for this colony was noted, this occurring in Lot 5, in which a single sealed larva was found to weigh 171.3 milligrams.

EFFECTS OF UNDERFEEDING.

It has been shown by Herms (*2*) and Whiting (*11*) for two species of the fly Lucilia (*L. caesar* L. and *L. sericata* Meig.) that undersized flies are produced by underfed larvæ. A similar condition is found in the boll weevil (*Anthonomus grandis* Boh.), in which it is stated that the size of the adult varies in almost direct proportion to the abundance of the larval food supply and the length of the period of larval development (*3*).

The following experiment was tried to determine whether the same relation exists between larvæ and adults of the honeybee. Ten larvæ, all decidedly below the average maximum weight, and therefore not fully fed, were taken from a normal colony, weighed and placed in artificial cells formed by making several deep cylindrical

grooves one-fourth of an inch in diameter in the surface of a flat block of wood which had been impregnated with melted wax. These cells were closed at the ends with wax and at the top with cover slips. The larvæ were then placed in an incubator and kept at 37.5° C. All of these larvæ spun more or less perfect cocoons, but only two succeeded in forming normal pupæ. From these two pupæ perfect adult bees emerged. The weight of these in milligrams, as compared with their larvæ and the weights of normal larvæ and pupæ, are given below:

	Larva.	Adult.
No. 1	115.0	68.1
No. 2	144.1	94.2
Normal	158.3	112.0

Since adult bees from fully fed larvæ reared under similar artificial conditions are only slightly under normal weight, it is possible to produce undersized bees from larvæ that are not fully fed. Undersized or dwarf bees are familiar to most beekeepers, but whether they are due to underfeeding of the larvæ is not definitely known.

METHODS, LOT 8.

In order to counteract variations observed in the earlier experiments as much as possible, an attempt was made during the work of 1922 to perfect the method suggested under Lot 7, which seemed to give promise of the best results. A space in the middle of a hive wide enough for two brood frames was partitioned off with queen-excluding zinc at either side and at the entrance. This was to prevent the queen from escaping in any way after the cover was placed on the hive, but the workers could come and go at will. A fairly strong colony of bees was transferred to this hive, placing one frame nearly filled with brood in this partitioned-off space, with a second frame either empty or with only a small amount of sealed brood in it. The queen was then confined in this chamber. The nearness of the well-filled brood comb to the empty comb generally induced the queen to lay a fairly large number of eggs in a period of 12 hours or less.

To obtain average live weights of larvæ of known age at definite age periods frames of eggs were removed from this chamber after a definite length of time. The frame removed was replaced by another empty one for the next series. The removed frame of eggs then was kept with several other frames of brood covered with nurse bees in a super over a strong colony, with the queen confined below by a queen excluder. After 3 days' incubation as eggs, at intervals of 24 hours each, larvæ were removed by means of small forceps for weighing. So far as possible, the time of day selected for weighing the larvæ corresponded to the middle of the egg-laying period for that series. A method of weighing similar to that previously employed was used, except that, to reduce the probable error, five larvæ were taken for each weighing instead of individual larvæ. Larvæ of average maximum size for the age period, and as nearly alike in size as possible when selecting from gross appearances, were chosen for each group of five. These were carefully removed, cleaned of food material, placed in a watch crystal, and weighed immediately by means of a chemical balance. Even with this method more or less variation in weight for each age period was

observed, but by comparing the weights given in Table 2 with the results given in Table 1 it may be seen that there is less variation with the method here described.

OBSERVATIONS, LOT 8.

EFFECT OF NO HONEY-FLOW.

As will be noted from Table 2, a majority of the weighings here recorded were made during August. In the region of the Bee Culture Laboratory (Somerset, Md., near Washington, D. C.) there is generally at this time of year an absolute dearth of incoming nectar and a consequent depletion of the reserve stores of the colonies. It was noticed that the average weights of the older larvæ, particularly of those over 4 days old, were consistently less than the values given in Table 1, Lots 1 to 5, for these ages, in certain cases as much as 6 to 8 per cent. In fact, many of the older larvæ that were presumably of the desired age were discarded because they were abnormally under weight. The weights for the age period below 4 days did not show this marked divergence, presumably because by the method used the variation in feeding in relation to the position of the larvæ on the frame was to a large extent eliminated. Most of the earlier observations (Lots 1 to 7) were made during June and July, at a time when there is generally some nectar flow from clover and other flowers sufficient to keep the bees from drawing on their reserve stores. It was suspected in these experiments that the lack of stimulation might be affecting the weights and rate of growth, thereby somewhat lengthening the larval period and lowering the maximum weights. The fact that the majority of the larvæ observed usually were not capped until about 18 to 24 hours later than most of those observed in Lots 1 to 7 seems to bear out this assumption of slower development.

No observations were made on the time period of emergence as adults, although the decrease in weight continued into the pupal period. It is known, however, that with certain other insects a scarcity of food often materially lengthens the developmental period. As stated above, insufficient food has a marked effect upon the weights of larvæ and even of adults.

Honeybee larvæ are peculiarly adapted for rapidly consuming and assimilating large amounts of food. Little energy need be expended except for the slight movements of feeding. Therefore practically all the food assimilated is used for the growth of tissues or is stored for future use as required during pupation. As a result the rate of growth should be more or less proportional to the composition and amount of the food consumed, and probably would be more noticeable with the more simple food of the later stages. Anything affecting the amount of this unpredigested food would consequently affect the rate of growth.

EFFECT OF STIMULATION.

In an attempt to demonstrate whether the above assumption is correct, several series of larvæ were subjected to conditions more nearly resembling the stimulative effects of a honey-flow. Frames containing eggs of known age were placed for development in a

strong colony which was fed a thin sugar sirup throughout the experiment, in order to stimulate activity. As a result, as will be noted from Table 2 and Figure 2, the weights of the older larvæ were noticeably increased under these conditions. In the case of the maximum-sized larvæ at the 6-day age, this amounted to as much as 8.1 per cent. This series was on the average sealed earlier than the previous series. These figures also more nearly correspond with those of Table 1.

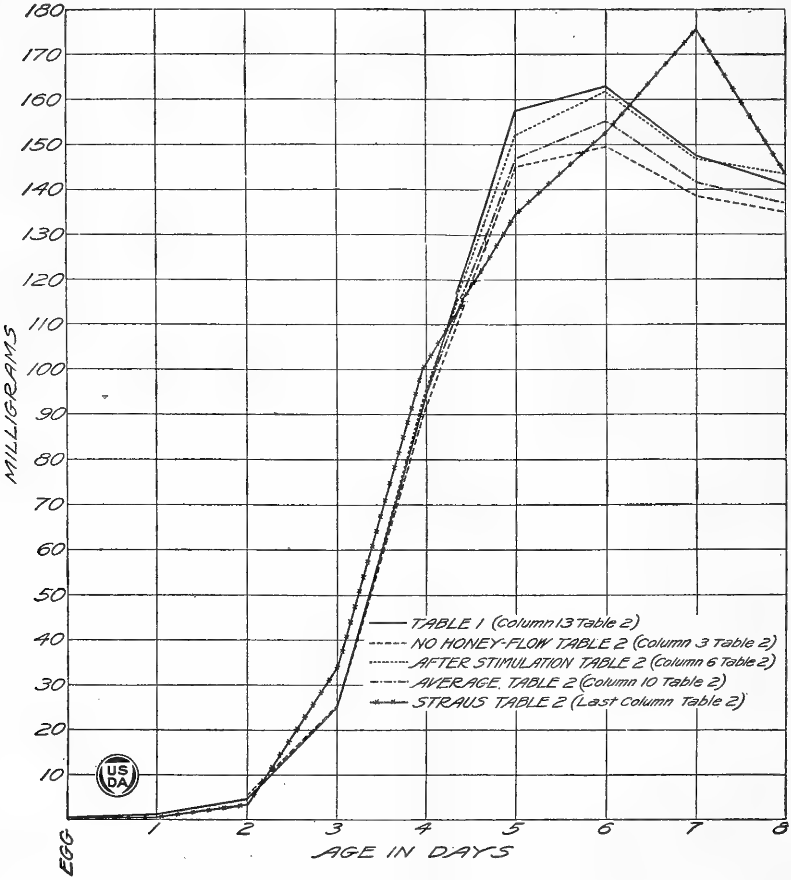

FIG. 2.—Living weights of honeybee larvæ at different age periods and under varying conditions. (Tables 1 and 2.)

Therefore, it seems safe to conclude that the amount of incoming nectar has an appreciable effect upon the development of at least the older larvæ. Weights of larvæ under 3 days old did not show this variation to any noticeable degree, there being only 1.7 per cent difference for the 4-day age and less for still younger ones. The curves shown in Figure 2 illustrate this point graphically. It will be noticed that the various growth curves, even to a relative extent that drawn from the Straus data, are almost identical for the first three days, only beginning to diverge on the fourth day.

NATURE AND COMPOSITION OF BROOD FOOD.

The foregoing observations have a bearing on the much discussed question of the source and nature of brood food at different times during the feeding period. The relation of the composition and amount of brood food to the rate of development may assist in explaining the variations observed above.

To obtain the weight of food unconsumed in the cells, as an indicator of the amount of food consumed in relation to the weight of larvæ of approximate known age, the following method was used:

A frame of brood was chosen from a normal colony, containing in an area of 2 or 3 square inches several larvæ of uniform size. The age of these larvæ was approximately determined by inspection and comparison in size with the drawings of larvæ of definite age (figs. 6 to 11). A piece of this comb was then cut out containing about the desired number of larvæ. The edges of this piece of comb were trimmed clean with a sharp scalpel and the cells of the comb were cut down so as to reduce the depth of the cells to about half. The edges and all cells containing larvæ of abnormal size not desired for weighing were cleaned and dried with swabs of absorbent cotton on the ends of matches. This was done as rapidly as possible so as to prevent loss by evaporation from the remaining cells. The piece of comb was then carefully weighed. The larvæ were then removed with fine forceps, care being taken to remove as little adhering food material as possible, and then the piece was weighed again. The difference between these two weights gives the approximate weight of the larvæ (Table 3). To obtain the weight of the remaining food, each cell was cleaned with a swab of absorbent cotton and the cell was then dried out thoroughly with a second swab to insure complete removal of all the food material. The weight of the empty comb was taken, by which the weight of the food material is determined. The average age of each lot was more approximately determined by comparison and interpolation with the weights of larvæ of known age, given in Table 2.

Unfortunately, owing to lack of time and the small number of determinations made, the data given in Table 3 are only approximately accurate. The data are suggestive, however, and considerable interesting information may be obtained by correlation with the rate of growth, the time of change in food composition, and the time spent by nurse bees in caring for the larvæ of various ages.

It is noticeable that the small, young larvæ are always surrounded by or even are floating on an excessive amount of food material, which has a uniformly grayish-white, pastelike consistency. From the data observed (Table 3, figs. 3 and 4), it was found that up to between the second and third days this excess of food, as indicated by the amount unconsumed in the cell, is considerably greater than the weight of the larva itself. There has been much controversy as to whether the food of the young larva is a secretion from glands or a regurgitation from the ventriculus [Snodgrass (*8*)]. Its consistent lack of pollen grains and uniform appearance suggest secretion rather than regurgitation, since if regurgitated it would of necessity contain undigested pollen grains, as these are always found in the ventriculus. If a secretion, the food of the younger larvæ would be affected much less by variations in external conditions, such

as dearth of nectar, while the food consisting mainly of honey and pollen, such as is fed to the older larvæ, could be affected by such circumstances, as the data given suggest.

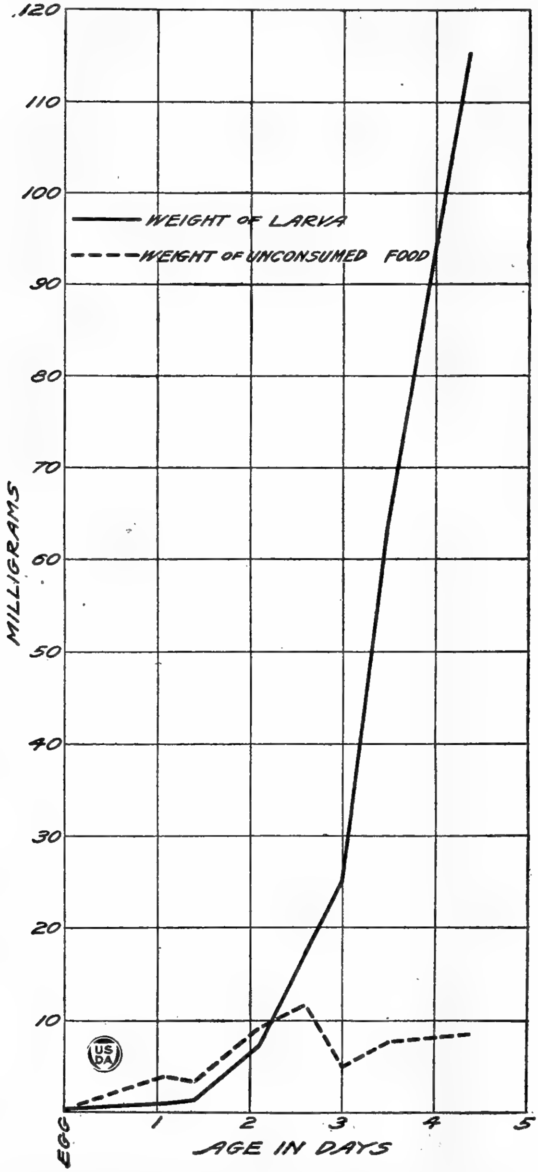

FIG. 3.—Weight of unconsumed food in the cell in relation to weight of honeybee larva. (Table 3.)

TIME OF CHANGE IN COMPOSITION OF BROOD FOOD.

It has been shown by the investigations of von Planta (7) (Table 4), that the younger larvæ receive a food that is much richer in fat and albuminous constituents than that given the older larvæ. In the case of the older worker larvæ this food is discontinued and a food consisting of a mixture of nectar (or honey) and pollen is substituted. The latter food was shown to be much higher in sugar content, while the fat and albuminous content decreases considerably. This food also contains undigested pollen grains, which are absent in the food of the younger larvæ. Von Planta stated that this change in the composition of the food occurs when the larva is 4 days old. From the observations of the writers, as well as of others, however, this change is found to take place as early as during the third day. This was demonstrated by the fact that throughout these experiments undigested pollen grains were regularly found in the food of larvæ no more than 3 days old from the time of hatching from the egg, often in sufficient amounts to color the food slightly. Also, as mentioned above, the coincidence of the curves in Figure 2 for rates of growth up through the third day even under

varying conditions strengthens this assumption. Larvæ destined to become queens, however, receive a highly nutritious food, "royal jelly," produced by the worker bees, throughout the entire larval period. It is well known that queen larvæ at maturity are larger and heavier than worker larvæ. Unfortunately, no weighings of queen larvæ were made, so that figures are not available for comparison with those of worker larvæ, but it is safe to assume that although they would raise somewhat the percentage increases for the last two days, yet the drop would doubtless still be evident.

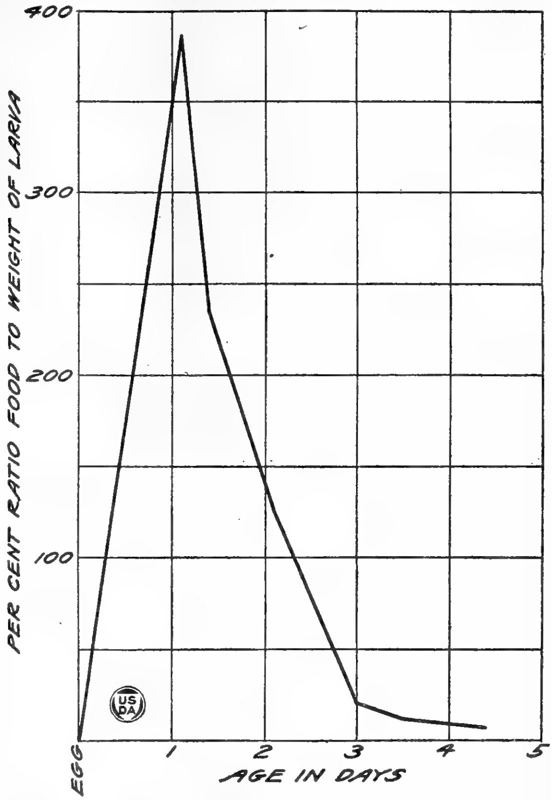

FIG. 4.—Per cent ratio of unconsumed food in the cell to weight of honeybee larva. (Table 3.)

RATE OF GROWTH.

The weighings recorded above are too few in number to justify broad generalizations, but are nevertheless of value in some particulars. The most obvious and striking feature is the remarkably rapid growth of the larva, which within 4½ to 5 days increases its initial weight more than 1,500 times. The ratio of initial weight to weight at maturity of several insects is shown below:

Cossus (*4*)	1 : 72,000	(Lyonet).
Sphinx (*6*)	1 : 9,976	(Newport).
Bombyx (*1*)	1 : 9,500	(Dandolo).
Telea (*10*)	1 : 8,600	(Trouvelot).
Apis	1 : 1,580	
Anthophora (*6*)	1 : 1,020	(Newport).
Sarcophaga (*2*)	1 : 451	(Herms).
Lucilia (*2*)	1 : 404	(Herms).

The first four of the insects listed above, as compared with the honeybee, have an extended larval period—3 years in the case of Cossus—and their food is of low nutritive value. In the case of the last four, particularly the honeybee, the larval food is of high nutritive value and is rapidly assimilated. In rate of growth the honeybee larva exceeds all of those listed, followed by the fly Sarcophaga, which attains 451 times its initial weight in about 71 hours.

In larvæ of the flies Sarcophaga and Lucilia, Herms (*2*), using the percentage increment method of Minot (*5*), found that "the tendency is for growth to decrease in rate uniformly." This rule does not apply to the honeybee, however, as the averages and percentage increases of all lots show (Tables 1 and 2). Moreover, the average per cent in each lot tends to reach a maximum at the end of the second day, with the exception of Lot 2 (Table 1). The individuals of this lot are open to the suspicion of being actually older than estimated. This suspicion, if confirmed, would explain the circumstance of the maximum per cent increment falling at the end of the first instead of at the end of the second day. After the second day the average percentage increment of the five lots combined shows a steady drop until maturity.

CORRELATION OF FOOD WITH THE RATE OF GROWTH.

Physiologically food may be defined as any substance taken in by an organism and made use of for any purpose. Nitrogenous material is necessary for growth and repair of tissues, no large amount being stored, except as tissue or protoplasmic substance. Sugars and fats are readily assimilated and stored in the tissues as glycogen and neutral fats and are sources of energy by oxidation for various purposes.

It is seen from Figure 5 that the greatest per cent of daily increase in growth for the honeybee larva takes place during the first three days of larval life, with the maximum at two days. After three days the per cent of daily increase is noticeably less, although the actual increase in weight of the larva rises rapidly to the maximum just after sealing has taken place. According to results of the analyses by Straus, when, during the first three days, the nitrogenous content of the food is high for the purpose of tissue building, relatively little storage of glycogen or fat takes place. Since little energy is required for the slight movements made by the larva, after the change in the composition of the food takes place and it becomes predominantly carbohydrate (that is, high in sugar content from the honey used), the great storage of glycogen takes place which is to serve as a source of energy during metamorphosis. This again seems to divide the larval period at about the 3-day age.

Again, as may be observed from the data given in Table 3 (figs. 3 and 4), at the time when the greatest relative increase in weight occurs and the food has the highest growth-producing, nitrogenous content, there is a marked excess of unconsumed food in the cells nearly four times the weight of the larva 1 day old. It will be noted that the weight of the 1-day-old larva (0.65 milligram) plus the weight of the food unconsumed in the cell on the first day (3.96 milligrams) practically equals the weight of the larva on the second day (4.745 milligrams) (Table 2). This relation does not continue, because the excess of food decreases, and the change in composition occurs soon afterwards. After the third day the larva has developed to a size sufficient to consume an increasingly larger volume of food as soon as it is placed in the cell, particularly as probably considerable food is actually placed directly in the mouth of the larva. This accounts for the small amount or almost total absence of food in the cells for the late stages just prior to sealing. There is a slight increase in weight, however, after sealing takes place. Therefore, correspond-

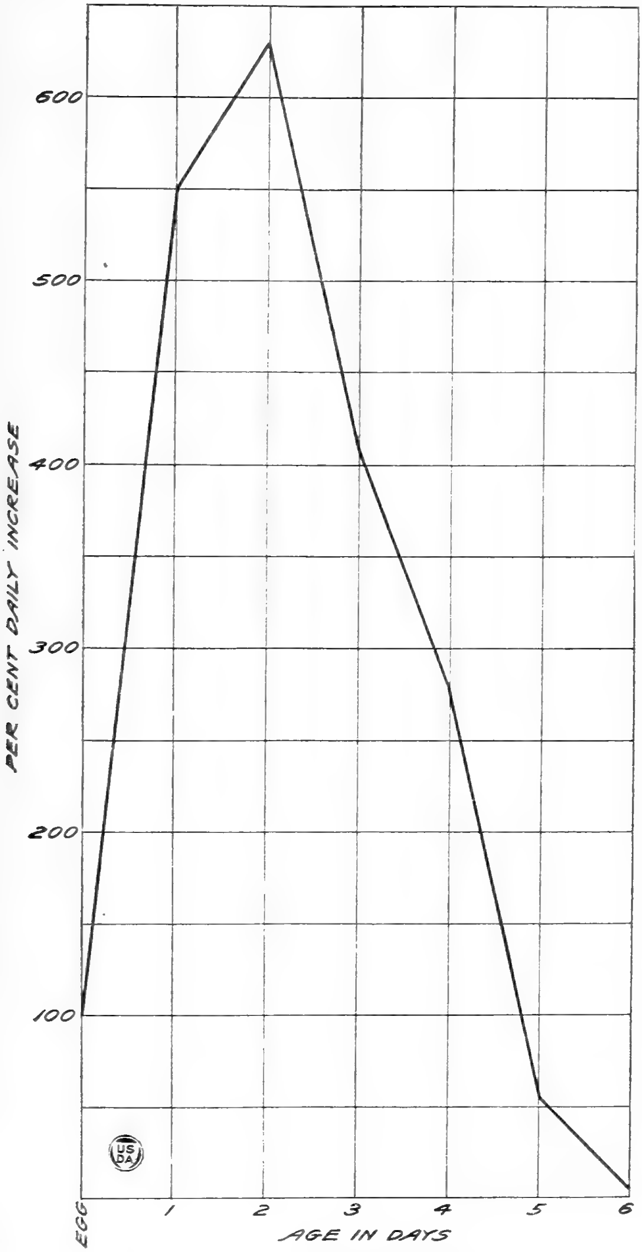

FIG. 5.—Per cent daily increase in weight of honeybee larva over weight of the preceding day. (Table 2.)

ing with the time of change in composition, the excess of food unconsumed in the cells greatly decreases in relation to the weight of the larva (fig. 4).

CORRELATION WITH TIME SPENT IN NURSING.

The effect of these food requirements upon the amount of work necessary to be done by the nurse bees in relation to the rate of growth of the larvæ and nature of the food is well illustrated by the observations of Lineburg in Part II of this bulletin. He found that in the time spent by nurse bees in caring for larvæ there is practically 100 per cent increase on the first day over that at the time of hatching from the egg. Food is never placed in the cell until soon after the larva hatches. On the second day this again decreases about an equal amount, but begins to increase again to a remarkable degree, particularly after the third day. From the third day on the living weight (fig. 2) and the time spent in feeding (fig. 13) show a remarkable correlation. The high point for feeding on the first day corresponds with the maximum excess of unconsumed food in the cells at this time. It seems probable that the nurse bees place an excess of the predigested food in the cell soon after the egg hatches, sufficient for the larva for about two days, so that only a minimum of attention is required until the change in the composition of the food takes place, at which time increasingly greater demands are made by the larva for honey and pollen.

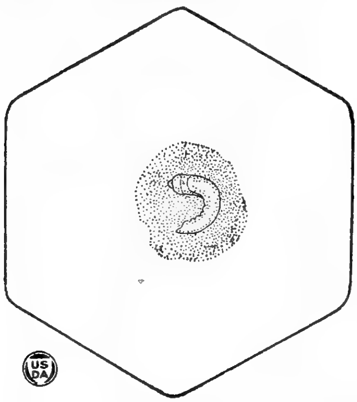

FIG. 6.—Larva of honeybee newly hatched from the egg.

Figures 6 to 11 were all drawn with the aid of the camera lucida from material preserved in alcohol. A special effort was made to secure as far as possible specimens representative of the average size of larvæ of the age designated. In figures 6 to 10, inclusive, the larvæ are represented as seen from the mouth of the cell, the outlines of the latter being represented by a hexagon and drawn accurately to scale.

Since the greatest relative increase in growth takes place during the period of uniform, highly nitrogenous food and the greatest storage of reserve energy-producing materials occurs after the food has changed in composition it may be assumed from the observations cited that any variations in honey-flow will affect the rate of growth of the older larvæ more than the younger larvæ.

GENERAL APPEARANCE OF LARVÆ OF DIFFERENT AGES.

The general appearance of larvæ of different ages, particularly with reference to their size and position in the cell, provides criteria by which to judge the age of the brood.

The newly hatched larva (fig. 6) has a total length of 1.6 millimeters. It is usually bent in a curve approximating a semicircle and lies on its side on the bottom of the cell. At this stage it is slender as compared with the later stages, tapers gradually from the head, and is nearly transparent. It usually lies near the center of the base of the cell in a mass of transparent larval food which does not exceed in diameter one-half that of the base of the cell. A circle drawn around the larva in its usual flexed position would closely approximate 1 millimeter in diameter (fig. 1). A larva may lie on either

its right or its left side, but in the accompanying figures the larvæ are all shown lying on the right side. Owing to the transparency of both the larva and the larval food in which it lies, it is often difficult to detect the presence of larvæ of this age without the aid of the microscope, especially when the brood comb is old and dark. In

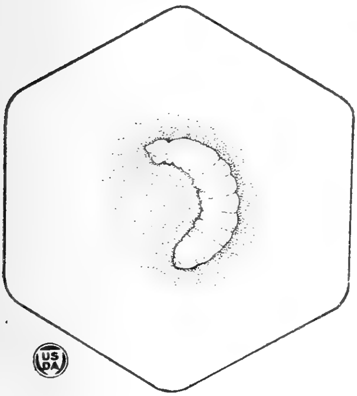

FIG. 7.—Larva of honeybee, 1 day old.

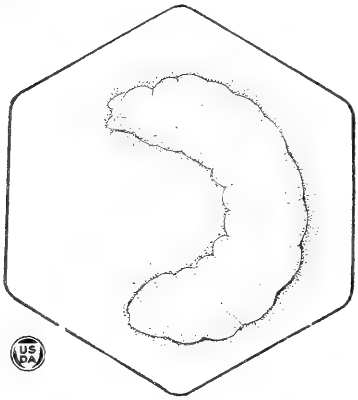

FIG. 8.—Larva of honeybee, 2 days old.

several instances newly hatched larvæ were found which were not provided with food, so that the presence of larval jelly is not necessary for the escape of the larva from the eggshell. Movement is frequently observed in young larvæ, but this is confined to simple extension and flexion of the body.

At the end of the first day the larva has attained a length of about 2.6 millimeters (fig. 7). It is now somewhat less transparent and the diameter of the posterior end of the body is now noticeably larger than that of the anterior end. The area of the base of the cell covered by larval food is proportionately greater.

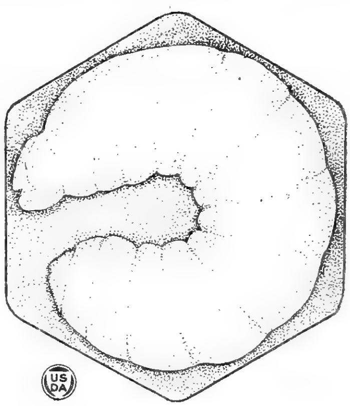

FIG. 9.—Larva of honeybee, 3 days old.

At the close of the second day (fig. 8) the larva measures slightly less than 6 millimeters in length and is still surrounded by food.

Larvæ 3 days old (fig. 9) are no longer bent in a semicircle, but form an incomplete ring, nearly covering the bottom of the cell. They are much less transparent than at earlier stages and begin to assume the opaque ivory-white appearance characteristic of the later stages.

At the end of the fourth day the larva (fig. 10) is bent to form a complete ring, the anterior and posterior ends overlapping, with the anterior end always above or outside the posterior end. The larva now snugly fits the bottom of the cell, but the two ends of the larva are still plainly distinguishable. Larvæ of this age no longer have

their food surrounding them, but a small amount of honey (nectar) mixed with pollen may be found on the base of the cell and adhering to the larva.

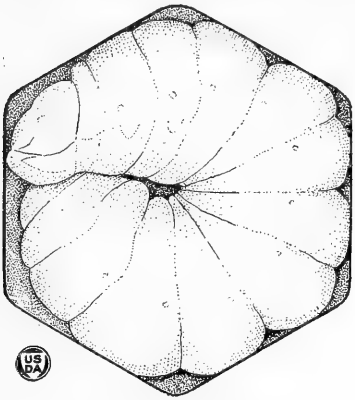

FIG. 10.—Larva of honeybee, 4 days old.

Full-grown larvæ (fig. 11)—that is, larvæ in cells more than half covered by the cap—fill the lower half of the cell so completely that the form of the larva suffers considerable distortion. The body is flattened and the head and tenth trunk segments are crowded back, telescoped into the neighboring segments, and, as the figure shows, are invisible from the mouth of the cell. Larvæ of this age, fixed and hardened in the cell, as was the one from which the figure was drawn, form veritable casts of the interior of the lower half of the cell. It should be noted that the head is always nearer the mouth of the cell than is the posterior end, the long axis of the larva thus following a spiral course.

SUMMARY AND CONCLUSIONS.

Eggs of the honeybee at the commencement of development weigh about 0.132 milligram each. At the close of embryonic development they weigh from 0.08 to 0.1 milligram each.

Larval development, up to the time of sealing, lasts $4\frac{1}{2}$ to $5\frac{1}{2}$ days. The average weights of the larva obtained from Lots 1 to 5 were as follows: First day, 0.65 milligram; second day, 4.687 milligrams; third day, 24.64 milligrams; fourth day, 94.692 milligrams; fifth day, 157.642 milligrams. Averaging the weights obtained under various conditions under Lot 8 the following weights were obtained: Second day, 4.745 milligrams; third day, 24.626 milligrams; fourth day, 93.99 milligrams; fifth day, 146.748 milligrams; sixth day, 155.005 milligrams; seventh day, 141.647 milligrams; eighth day, 137.165 milligrams; ninth day, 133.152 milligrams. Weights after the fifth day are of sealed brood.

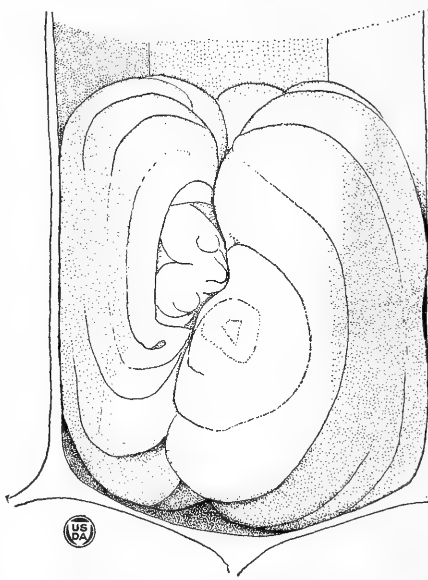

FIG. 11.—Mature honeybee larva, the half of the cell facing the observer being removed so that the larva is shown as seen from one side of the cell, and not from the outer end, the base of the cell being toward the bottom of the page.

The increase in growth, measured by percentages, tends to attain a maximum at the close of the second day and from that time steadily declines until the close of larval development.

Great individual differences in weight are noted between different lots of the same age and between different individuals of similar age in the same lot.

The maximum average weight appears to be fairly constant, at least for the same colony under similar conditions.

Stimulating the activity of the bees by feeding a thin sugar sirup during a dearth to produce the effect of a honey-flow was found to cause an increase in the weight of larvæ 4 days old and above, to as much as 8 per cent in the case of 6-day-old larvæ (just sealed).

The weights of larvæ over 3 days old are found to be affected by variations in the honey-flow, the rate of growth decreasing under conditions of dearth.

Sealing of the cell is begun before the larva has attained its final weight, and about one-third of the mouth of the cell is covered before this weight is attained.

Great differences exist in the time of the sealing of the cells of a given lot of larvæ of the same age, a period of several hours intervening between the sealing of the earliest and that of the latest cell.

Undersized or dwarf bees may be produced from larvæ that are not fully fed.

From the various observations made, the change in the composition of the food of the honeybee larva, from one of high nitrogenous content to one of high sugar content, takes place as early as the third day after hatching from the egg.

The excess of weight of food unconsumed in the cell before this change in food composition occurs is correlated with the uniformly great relative increase in growth of the larva during the first three days of larval life. All later changes in the rate of growth are correlated with the condition of the honey-flow.

The time spent by the nurse bees in nursing, as observed by Lineburg, is correlated with the demands of the larvæ for the different types of food before and after change in composition occurs.

TABLE 1.—*Weights of the bee larvæ of five lots, at intervals of 24 hours (1915 and 1916).*

Lot No. and age in days.	Total weight.	Number of larvæ.	Average weight.	Average daily increase.	Daily increase.	Remarks.
Lot 1:	*Mg.*		*Mg.*	*Mg.*	*Per cent.*	
Eggs	2.00	20	0.100	....	....	
0 day	1.00	10	.100	....	....	
1 day	4.45	10	.445	0.345	345	
2 days	27.55	10	2.755	2.310	519	
3 days	76.30	5	15.260	12.505	454	
4 days	333.10	5	66.620	51.360	337	
5 days	778.15	5	155.630	89.010	134	Larvæ partly sealed.
Lot 2:						
1 day	10.20	10	1.020	[1] 0.920	[1] 920	
2 days	53.50	10	5.350	4.330	425	
3 days	188.40	5	37.680	32.330	604	
4 days	597.50	5	119.500	81.820	217	
4½ to 5 days	[2] 2,374.70	[2] 15	[2] 158.313	[2] 38.813	[2] 32	Larvæ sealed.
Lot 3:						
1 day	5.70	9	0.633	[1] 0.530	[1] 530	
2 days	45.10	5	9.020	8.387	1,325	
3 days	114.80	5	22.960	13.940	155	
4 days	638.80	5	127.760	104.800	456	Sealing begun.
4½ to 5 days	[2] 2,374.70	[2] 15	[2] 158.313	[2] 30.553	[2] 24	Sealing completed.
Lot 4:						
1 day	3.05	5	0.610	[1] 0.510	[1] 510	
2 days	31.75	5	6.350	5.740	941	
3 days	166.50	5	33.300	26.950	424	
4 days	502.70	5	100.540	67.240	202	Sealing begun.
4½ to 5 days	[2] 2,374.70	[2] 15	[2] 158.313	[2] 57.773	[2] 57	Sealing completed.
Lot 5:						
1 day	5.20	10	0.520	[1] 0.410	[1] 420	
2 days	29.60	10	2.960	2.440	469	
3 days	70.10	5	14.020	11.060	374	
4 days	295.20	5	59.040	45.020	321	
5 days	727.80	5	145.700	86.660	147	Sealing begun.
5½ to 6 days	[2] 2,374.70	[2] 15	[2] 158.313	[2] 12.613	[2] 9	Sealing completed.
Average of Lots 1 to 5:						
0 day	1.00	10	0.100	....	....	
1 day	28.60	44	.650	0.550	550	
2 days	187.50	40	4.687	40.370	621	
3 days	616.10	25	24.640	19.928	426	
4 days	2,367.30	25	94.692	70.052	284	
4½ to 5 days	3,152.85	20	157.642	62.950	66	Larvæ attain maturity.

[1] Based on difference between the first day's weight and the weight of the egg as given for Lot 1.
[2] Figures obtained from weighing in 1916 of 15 mature larvæ from the same colony as Lot 1.

TABLE 2.—*Lot 8 (1922): The average weight in milligrams and the rate of growth of honeybee larvæ at different age periods in days from the time of hatching from the egg, under varying conditions.*

Age.	No nectar flow.			Stimulative feeding.			Effect of feeding.		Final average.	Rate of growth.		Table 1, Lots 1-5.		Straus.
	Date.	Weights.[1]	No.	Date.	Weights.[1]	No.	Difference in weights.	Per cent increase.		Average daily gain.	Per cent daily gain.	Weights.	Per cent daily gain.	Weights.
Egg												0.100		0.060
1 day [2]										[3] 0.550	[3] 550	.650	550	.300
2 days [2]	Aug. 11	3.96	5											
	Do	4.68	5											
	Do	5.30	5											
	Do	4.86	5											
	Do	5.34	5											
	Do	5.20	5											
	Do	3.80	5											
	Aug. 14	4.60	5											
	Do	4.48	5											
	Do	4.62	5											
	Do	4.70	5											
	Do	5.40	5											
Average		*4.745*							4.745	4.095	630	4.687	621	3.400
3 days [2]	Aug. 12	20.96	5											
	Do	24.12	5											
	Do	20.36	5											
	Do	18.96	5											
	Aug. 15	29.02	5											
	Do	21.16	5											
	Do	26.38	5											
	Do	29.52	5											
	Do	22.46	5											
	Do	27.28	5											
	Do	24.64	5											
	Do	29.66	5											
	Do	25.64	5											
	Do	25.10	5											
	Do	24.14	5											
Average		*24.626*							24.626	19.881	419	24.640	426	33.300

[1] Averages in italics.

[3] Unsealed.

[3] From Table 1.

TABLE 2.—*Lot 8 (1922): The average weight in milligrams and the rate of growth of honeybee larvæ at different age periods in days from the time of hatching from the egg, under varying conditions.*—Continued.

Age.	No nectar flow.			Stimulative feeding.			Effect of feeding.		Final average.	Rate of growth.		Table 1, Lots 1-5.		Straus.
	Date.	Weights.[1]	No.	Date.	Weights.[1]	No.	Difference in weights.	Per cent increase.		Average daily gain.	Per cent daily gain.	Weights.	Per cent daily gain.	Weights.
4 days[1]	Aug. 16	80.86	5	Aug. 30	94.96	5								
	Do	90.48	5	do	97.50	5								
	Do	98.08	5	do	93.38	5								
	Do	84.44	5	do	94.60	5								
	Do	102.56	5	do	94.40	5								
	Do	100.62	5	do										
	Do	107.37	5											
	Do	82.62	5											
Average		*93.378*			*94.968*		1.590	1.7	93.990	69.364	282	94.692	284	100.100
5 days	Aug. 14	[1] 142.38	5	Aug. 31	[2] 149.58	5								
	Do	[1] 146.88	5	do	[2] 155.40	5								
	Aug. 15	[1] 142.02	5	do	[2] 151.58	5								
	Do	[1] 146.82	5	do	[2] 146.02	5								
	Do	[1] 140.92	5	do	[2] 148.00	5								
	Do	[1] 142.62	5	do	[2] 156.48	5								
	Do	[1] 140.22	5											
	Aug. 17	[1] 142.88	5											
	Do	[1] 142.52	5											
	Do	[1] 151.98	5											
	Do	[1] 149.32	5											
	Do	[1] 141.54	5											
	Do	[1] 149.92	5											
	Do	[2] 147.88	5											
Average		*144.85*			*151.177*		6.327	4.4	146.748	52.758	56	157.642	66	134.500
6 days[3]	Aug. 15	152.54	5	Aug. 31	159.13	25								
	Do	155.92	5	do	164.99	25								
	Do	152.52	5											
	Do	155.70	5											
	Aug. 18	147.92	25											
	Do	148.65	25											
Average		*149.966*			*162.06*		12.094	8.1	155.005	8.257	5.6	[4] 162.900	[4] 3	153.200

7 days[3]	Aug. 16	138.60	5	Sept. 9	148.22	5								
	Do	134.24	5	do	145.68	5								
	Do	132.30	5	do	148.04	5								
	Do	143.90	5											
	Do	144.36	5											
	Do	139.49	5											175.600
Average		*138.815*			*147.31*		8.495	6.1	141.647	−13.357	−8.6	[4] 147.700	[4] −9.0	147.200
8 days[3]	Aug. 17	138.92	5	Sept. 8	144.76	5								
	Do	130.26	5	do	142.92	5								
	Do	135.54	5	do	143.70	5								
	Do	136.98	5											
	Do	133.20	5											
	Do	133.68	5											
	Do	136.17	5											
	Do	134.76	5											
	Do	135.10	5											
Average		*134.956*			*143.79*		8.834	6.5	137.165	−4.482	−3.2	[4] 141.200	[4] −4.4	143.000
9 days[3]	Aug. 18	133.62	5											
	Do	130.76	5											
	Do	133.16	5											
	Do	134.56	5											
	Do	133.66	5											
Average		*133.152*							133.152	−4.013	−2.9			142.000

[1] Unsealed. [2] From Table 1. [3] Sealed. [4] From manuscript notes, Lots 1 to 7.

TABLE 3.—*Ratio of weight, in milligrams, of unconsumed food in cell, to weight of larva at different approximate age periods.*

Approximate age.	Number of observations.	Average weight of food per cell.	Average weight of larvæ.	Per cent ratio, food to larva.
Egg	Several.	None.	0.10	0
1.1 days	33	3.96	1.02	388
1.4 days	131	3.23	1.36	238
2.1 days	24	9.10	7.20	126
2.6 days	35	11.79	17.48	67
3 days	25	5.05	25.22	20
3.5 days	65	7.75	63.46	12
4.4 days	17	8.76	115.15	8

TABLE 4.—*Composition of larval foods—von Planta* (7).

Composition of dried substance.	Queen.	Drones.		Workers.	
		Under 4 days.	Over 4 days.	Under 4 days.	Over 4 days.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nitrogenous products	45.15	55.91	31.67	53.38	27.87
Fat	13.55	11.99	4.74	8.38	3.69
Sugar	20.39	9.57	38.49	18.09	44.93

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PART II. THE FEEDING OF HONEYBEE LARVÆ.

CONTENTS.

INTRODUCTION.

The larvæ of most bees are supplied with a mass of food consisting of a mixture of pollen and honey, which is put in place before the egg is laid. The larvæ of the honeybee, on the other hand, are fed at frequent intervals during the period of larval life. This behavior of the honeybee involves the services of nurse bees in caring for the larvæ. The nurse bees are always worker bees, usually those less than a month old. When worker bees are acting as nurse bees they take honey (or nectar) and pollen from adjacent cells of the comb and from these two materials elaborate the food on which the larvæ live and grow to maturity.

The food given to the youngest larvæ is a grayish-white paste-like material which is placed in the cell beside the larva. For older larvæ the prepared food is mostly fed directly to the larvæ. To supply food to a larva the nurse bee must enter the cell head first, so that it is impossible for one to see what occurs in the cell while the nurse bee is so situated. Because of the fact that the larva is wholly hidden while the worker is attending it, one can determine only the total time spent in this work, without being able to divide the time according to the various actions which may occupy the nurse bee during this activity. Attention was attracted to this phase of the feeding problem by the observation that nurse bees spend considerably more time in cells containing well-developed larvæ than they do in cells containing eggs or young larvæ. To get accurate data on the inequality of the time spent in feeding the present observations were begun.

As explained in Part I of this bulletin, Mr. Sturtevant was at the same time engaged in determining the rate of growth of the worker larvæ. His results showed such a striking correlation with those obtained for the time spent by the nurse bees in feeding that it was decided to cooperate in determining the correlation of the weight of larval food contained within the cell during each day of the larval period with the weights of the larvæ for each day. These results have been incorporated in Part I.

METHODS.

All observations were made on a colony of bees in a dark room, using artificial light. The hive used was especially designed to exclude all light from the brood nest except that used by the observer.

An entrance to the hive was gained by means of a maze tunnel leading through the wall of the room which excluded all light. The bees traveled in total darkness for a distance of approximately 6 inches before entering the hive proper.

The reason for placing this hive in a dark room was that when bees are kept in an observation hive out of doors they tend to congregate on the glass and thus hide the activities of the nurse bees to too great a degree for such observations. It was found that this does not occur when bees are kept in such a hive in a dark room for a considerable period.

The hive used was of standard 10-frame dimensions, containing 10 drawn combs which previously had been used for rearing brood. Several of these combs contained brood when placed in the hive and some of the combs contained sealed honey above the brood. The colony was of average strength for a colony kept in a single hive body. During the course of the observations the worker bees apparently flew in normal numbers to the field. Supplies were collected and brood was reared in numbers that justify the statement that the behavior of the bees, both workers and queen, was approximately normal. The observations extended from August 25 to September 9, 1922, during which period little nectar was coming in. A small amount of sirup was given once.

Various arrangements of electric lamps were tried so as to secure the best lighting, but best results are obtained by using a 40-watt lamp, which is placed on the top of the hive and back from the edge far enough to exclude all direct rays from the comb. A mirror attached to a flexible support is then adjusted so that the rays from the lamp are reflected to the portion of the comb under observation. The hive is slightly above the level of the eyes, and when the eyes are placed just behind and a little below the mirror an excellent view of the interior of the cell is obtained. A concave mirror is best for close inspection of the contents of a cell, while a small plane mirror is best for ordinary observations. Shades are attached to the sides of the mirror to protect the eyes from direct light from the lamp.

Under normal conditions in a hive containing a number of combs the brood nest is in the inner combs, and this makes impossible observations of what takes place during feeding. To obviate this difficulty, combs containing larvæ of the desired age were taken from the center of the brood nest and placed next the glass. The hive was well filled with bees of all ages, and at once the nurse bees appeared and took up their duties as attendants on the outside of the comb, where their activities could be observed readily.

On one occasion all brood was removed from the hive and empty combs partially filled with sirup were put in. A single frame of brood of the desired age was then placed in the hive next the glass. On this occasion the queen appeared on the outside of this comb, where she remained for one hour. During this period she laid a number of eggs, rested, and was fed, in a manner suggesting normal conditions. Several flashlight pictures of the laying queen were taken, but even these flashes failed to drive her to the other side of the comb.

The cells to be studied are either marked before the comb is placed in the hive or selected by a close study with the concave mirror after

the comb is placed in the hive. These cells are then marked by pasting a small triangular pointer on the outside of the glass, the fine point of which comes directly over the cell to be studied. These pointers serve to hold abbreviated data concerning the particular cell which they mark; they interfere in no wise with the observations and are permanent. Paint or marks on the edge of the cell itself are soon removed, and the bees working at this removal may introduce a source of error.

Preliminary observations were made, and it was decided that 10-minute periods for observations are probably of the most practical length. Such a short period can be used to obtain data on a greater number of different cells within a given time, or they can be doubled and several readings taken in succession on the same cell, in case it appears that either procedure is desirable.

NURSE BEES.

A nurse bee moves about over the brood combs when attending to the needs of eggs or larvæ. She stops sometimes and lowers her head over certain cells, and at other times she thrusts her head within the brood cells but promptly withdraws it. On still other occasions she enters a cell containing an egg or a larva and remains in it for a more or less extended period, presumably engaged in certain activities. The activities of the nurse bees in their work may be classified according to the time spent at each cell and according to the probable purpose of their visits. These actions are here divided into inspections and nursing, and the inspections are further subdivided.

INSPECTION, TYPE A.

A nurse bee in pursuing her duties sometimes pauses with her head over an open brood cell. When she does this she usually lowers her head slightly, barely perceptibly at times, and then passes on. It is observable that she is a nurse bee, and presumably this behavior is part of the activity connected with her duties as a nurse, for she has just come from another cell where she has been feeding a larva; and if her movements are followed, she is seen to enter another cell, where her movements indicate that she is attending to the wants of the inmate.

This act of pausing, together with other activities which may accompany it but which have not as yet been explained, is difficult to classify, because its significance is not known. Such a pause may be all that is required to gain information through some sense organ concerning the feeding requirements of the inmate, and therefore this activity must be recorded. This type of activity is frequently noted, particularly when the cell contains an egg or a young larva.[1] At present certain and special significance can not be attributed to this activity other than calling attention to it as a fact; it was decided to enter it in the data under the designation Inspection, Type A.

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[1] A similar hesitating behavior is noted in the case of the laying queen, and it is seen most often when she is laying in a comb containing scattered brood and eggs. At such times she frequently pauses above certain cells and then passes on without entering. Many cells thus passed have been examined and practically without exception they contained either eggs, larvæ, or noticeable débris.

INSPECTION, TYPE B.

On other occasions a nurse bee approaches an open brood-cell, pauses, lowers her head and thrusts it into the cell, but withdraws it almost immediately. The whole head may be thrust within the cell and perhaps part of the thorax as well. When the whole time of this operation does not exceed two seconds, it is assumed that there is not time for the nurse bee to do anything in the nature of actual feeding. Two seconds might allow time for the ejection of a liquid food, but such a short time is probably insufficient for a determination of the already available food supply or the needs of the larva and then additional time for supplying such food as may be needed. In taking data on the time spent in caring for the brood, all such activities are designated Inspection, Type B. That bees do determine the quantity of food present is evidenced by the fact that all larvæ of approximately the same age and position on the comb have about the same amount of food at all times. This would not be the case if the different nurse bees did feeding indiscriminately and without a determination of the amount of food already within the cell. There is opportunity in the form of activity under this heading for tactual contact with the larva, while in the former type (Type A) there is no such opportunity.

NURSING.

Feeding of the larva occurs when the nurse bee enters the cell, but obviously an appreciable time is required for this activity. For such activity the descriptions under the two preceding types of inspection are not valid. While the nurse bee is within the cell, activities other than actual feeding may occupy part of her time, but probably all these activities have to do with the care of the larva.[2]

The time spent by a nurse bee within the cell engaged in feeding varies between 2 seconds and from 3 to 4 minutes. Even the shortest periods may be distinguished from inspection by the fact that there is a noticeable pause of the bee while within the cell. The longest periods mentioned are quite exceptional. It is impossible to see what a nurse bee is actually doing within a cell, but some basis for a differentiation between inspecting and nursing visits should be adopted, even though it appears more or less arbitrary. The most practical basis appears to be that of time. When the time spent within the cell is less than 2 seconds the visit is classed as an inspection, and when the visit is of longer duration it is considered under the designation nursing. This basis does not appear so arbitrary to the observer, since the actual behavior in these two cases appears rather more distinctive than the difference in time alone would cause one to believe. While it is quite possible that occasionally an inspecting bee may spend more than two seconds, it is nevertheless true that most inspection visits are completed in less than two seconds.

Having, therefore, decided upon this method of classification of the behavior of the nurse bees, observations were begun. The results

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[2] Occasionally a worker bee creeps into a brood-cell containing a small larva merely to rest. Such a worker may usually be distinguished promptly from a nurse bee engaged in her duties of feeding.

obtained in the observations are presented in Tables 5 to 7 and in Figures 12 and 13.

NUMBER OF VISITS.

Observations were made for each group of larvæ to determine the actual number of visits of nurse bees to the eggs and larvæ under observation, each egg or larva being watched individually for a 10-minute period, as previously stated. The data given in Tables 5 to 7 show the details of these observations. The average number of visits for a 10-minute period to the egg and to larvæ of ages from 1 day to 5 days were, respectively, as follows: 5.93, 6.40, 5.79, 8.08, 14.47, 19.83 (Table 6 and fig. 12). Of the visits listed as Inspection, Type A, there is no great change in the number as the larvæ increase in size and age, the slight variations being probably without great significance (Table 5). The number of visits listed as Inspection, Type B, increases as the larvæ grow larger and older, while the number of visits listed as nursing, in which the nurse bee stays in the cell at least two seconds, show no great significant variation until the fourth day of larval life, when there is a great increase in the number, followed by still further increase on the fifth day. It is significant that there is no marked decrease in the total number of visits on the second day of larval life, although, as will be discussed later, there is at this time a decrease in the amount of nursing.

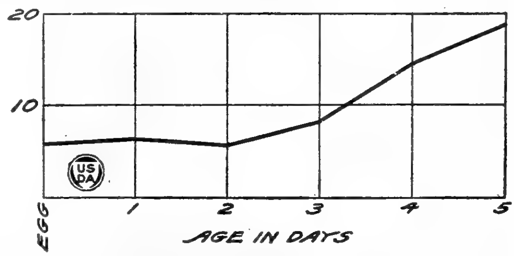

FIG. 12.—Showing the relation of the number of visits made in nursing honeybee larvæ per 10-minute period to age. (Table 6.)

From the foregoing it readily can be seen that the egg and larva are under the almost constant observation of the nurse bees, and that under such a system of visitations there is little likelihood of any individual being overlooked for any considerable length of time.

TIME SPENT IN NURSING.

Observations were also made for each age to determine the total time spent by the nurse bees with the eggs and larvæ under observation, each egg or larva being also watched for a 10-minute period. The details are given in Table 5. The average time in seconds spent by nurse bees for a 10-minute period with the eggs and larvæ of ages from 1 to 5 days were, respectively, as follows: 6.5, 20.73, 5.93, 11.42, 41, 118.08 (Table 7 and fig. 13). It should be noted that the visits here discussed are only those listed as nursing, and no account is here taken of the shorter visits listed as inspection of the two types. There is observed a decided increase in the amount of time spent in nursing as the larvæ grow in size and age, the outstanding exception being for larvæ 2 days of age, which will be discussed later. The total time spent in feeding during the five days of larval life is 6.57 per cent of the whole time, while on the fifth day, when the larvæ are largest and require the most food for their development, the

nurse bees actually spend within the cell 19.68 per cent of the whole time. These figures indicate the unceasing care of the developing bees even more than do the data on the number of separate visits made to them by the nurse bees.

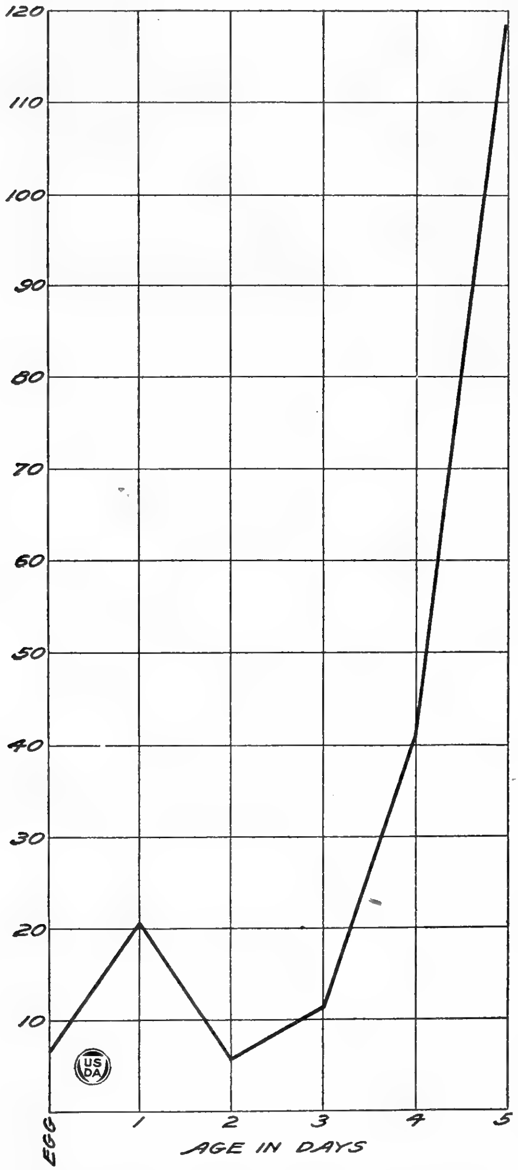

FIG. 13.—Showing the relation of average time (seconds) spent in nursing honeybee larvæ per 10-minute period to age. (Table 7.)

Few successive observations on individual larvæ were made, since the number of visits and the time spent within the cells were fairly uniform for each age. Occasionally, where a particularly small or a particularly large total was obtained for a certain cell in one 10-minute period, a second observation was made at once. Usually in such cases the average of two such readings was about equal to the average per 10-minute period for the given age. It therefore appears that if a cell has received more than the usual amount of attention during one observation period of 10 minutes, the nurses during the ensuing period devote less than the average amount of attention to that particular cell, though they may inspect it as many or even more times than they did during the preceding observation period. Likewise any slighting of a certain cell during one period is compensated in a subsequent period by more than the average amount of attention.

CHANGE IN FEEDING BEHAVIOR.

It has long been known that the developing larva is not fed the same kind of material throughout larval life, it being usually believed that the change in the character of the food occurs on the fourth day. The data herein recorded show not only that such

a change does occur, but that there is also a remarkable change in the type of feeding, and that this change occurs at the time when the character of the food changes. It thus becomes necessary to point out that the change in food occurs not on the fourth day, as commonly stated, but much earlier. This is further substantiated by the work done by Sturtevant and the writer, recorded in Part I of this bulletin.

As has been stated earlier, the number of visits for each 10-minute period averages 5.93, 6.4 and 5.79 for the egg, 1-day, and 2-day larvæ, respectively. For these same ages the time in seconds spent in nursing (each period more than two seconds) is as follows: 6.5, 20.73, and 5.93. Such a change, on superficial consideration, appears inconsistent, since one naturally supposes that a 2-day larva would require more visits and more time spent in nursing than does the egg or the 1-day larva. The time spent in nursing the 1-day larva is actually over three times as great as the time for the 2-day larva.

This whole matter is unexplained until it is viewed in the light of the results obtained by Sturtevant and the writer in Part I of this bulletin on the amount of food found within the cell for larvæ of different ages. No food is ever found in the cell with the egg, while the weight of food within the cells containing 1-day and 1.4-day larvæ averages 3.96 and 3.23 milligrams, respectively. If now these findings are taken into consideration with the well-established fact that there is a change in the character of the food of the worker larva, the whole matter is explained. Immediately following the hatching of the egg, the nurse bees surround the young larva with food in relatively large quantity. As pointed out, this first supply of food may weigh 3.96 milligrams per cell, which is equal to almost four times the weight of the young larva which it supplies. These figures indicate that, as already suggested, a large amount of food is placed in the cell of the recently hatched larva and that during the second day little or no feeding is done, since the attention given (in number of visits as well as in time in nursing) is about equal to that given the egg. Since the egg is never surrounded by food, this indicates that the attention given the 2-day larva is of no greater significance than that given the egg, so far as the giving of food is concerned. That there is a rapid giving of food on the first day followed by little or no supplying of food on the second day is further supported by a comparison of the weights of food contained in the cells with larvæ of these ages. Nelson and Sturtevant show that there is a decrease of 0.73 milligram in the amount of food in the cell on the second day. During this interval there is an increase in the weight of the larva of 0.34 milligram so that the decrease in weight of available food exceeds the increase in weight of the larva. The difference (0.39 milligram) is doubtless accounted for by the total combustion of food by the rapidly growing larva. Larvæ of this age are doubtless too small to ingest more than the amount of food represented by the decrease in weight of the available food, from which it follows that little or no food is given the larva on the second day.

On the third day there is a slight increase in the amount of time spent by the nurse bees within the cell, and this indicates that feed-

ing is being resumed. Further evidence to substantiate this conclusion is found both by weighings of the food present and by a comparison of the composition of food found in cells containing 2-day and 3-day larvæ. Sturtevant shows that there is a considerable increase in the amount of food found in cells containing 3-day larvæ over the amount found with 2-day larvæ. The composition of the food is changed also by the third day. This is most conspicuous through the fact that the color of the food found within the cells containing larvæ of 3 days or more varies with the color of the pollen being brought in from the field, no stores of old pollen being present in the hive used in this experiment. The larval food found in cells containing 1-day and 2-day larvæ is of a uniformly grayish-white color.

With the change of food it appears that a different method of feeding is gradually adopted, mass feeding giving place to progressive feeding; that is, the food is no longer given in quantity and in excess of immediate needs, but is supplied at about the same rate at which it is ingested. The bee larva is a rapidly growing organism, hence it follows that if the food is supplied from time to time, it must be introduced in rapidly increasing amounts. This necessitates either more visits or longer feeding periods, or both of these factors may be increased. The last is actually the case. The number of visits is increased, particularly on the fourth and fifth days, and the time of the visits is notably lengthened.

Mass feeding, if this is strictly what happens in the case of the food first supplied, taken together with the later progressive feeding, shows an interesting similarity to the behavior of certain solitary bees, some of which practice mass feeding exclusively, while others, recently investigated, practice progressive feeding. It also has a resemblance to the feeding behavior of the bumblebee, which lays the eggs on a lump of "pollen-paste" to furnish the first food after hatching, and then some time after the larva is hatched a type of progressive feeding is begun. A similarly modified type of mass feeding is shown in the case of the queen larvæ of the honeybee. The large queencell is rapidly crowded with food before it is sealed, and the larva completes its development while eating more food which is inclosed with it. Frequently a mass of dried food remains even after the emergence of the queen, which confirms the supposition of mass feeding in this instance.

The fact that the food of the larva up to 2 days is placed in the cell beside the larva and is apparently not fed into the mouth seems to preclude the possibility of mutual feeding of the nurse bee and larva during this period. Such reciprocal feeding has been described for certain social wasps and ants, and to this phenomenon Wheeler has given the name trophallaxis. Since the queen larva is also fed by mass feeding, perhaps exclusively by that method, there is little or no indication of trophallaxis in this instance. Roubaud has shown that in certain wasps in which trophallaxis is observed there is a decided disproportion between the amount of material given by the nurse wasp and that received by it from the larva being fed, the secretion received being sometimes greater than the food given by the nurse. Reciprocal feeding has never been observed in the honeybee, but since the food given to the older larvæ is not complex in character and probably requires no great amount of work on

the part of the nurse bees for its elaboration, it is difficult to explain the great amount of time spent by the nurse bees in the cells merely on the basis of the belief that food is being fed to the larva all that time. That the usual method of feeding is directly to the larval mouth is clear from the fact that no significant amount of food is ever found in the base or on the sides of the cell of an older larva. In the determinations of the weight of food residue in the cell it is noteworthy that for each age it is quite uniform. If one dared to assume reciprocal feeding, this might perhaps account for the peculiar development of the worker bee in the repression of the sex organs and other morphological modifications. Wheeler has shown that parasites like Orasema, by the withdrawal of food substance already assimilated by ant larvæ, may bring about morphological changes of the same kind as those which distinguish the worker ant from the queen.

The number of inspections and visits to the egg may be accounted for, in the light of present knowledge, only by the assumption that they are due to the watchfulness of the nurses, since they feed the young larvæ promptly on hatching. In no other cases except in the ants are insects known to care for the eggs. Ants lick the eggs, but this is supposed to be for the purpose of sticking them together so that they may be transported in quantity.

THE LABOR OF THE NURSE BEES.

Contrary to the common belief, it was noted that bees are not outstanding examples of industry. During these observations much resting was observed both among the nurse bees and among the other workers. Demuth has observed that the average number of trips to the field often does not exceed four per day, whereas the time required for making such trips and the time required to deposit the supplies obtained might readily permit a much larger number. Such an apparent lack of industry concerns the present problem only in that it is evident that more nurses will be required for a given number of larvæ in proportion to the time that is taken off from their active duties. In the case of nurse bees, however, other considerations enter, since considerable time may be required for the elaboration of larval food. Thus it is quite possible that a nurse bee, though apparently idle so far as one can determine, may be active physiologically in the production of larval food. Any determination of the efficiency of a single nurse bee may be made only by observations on a large number of individual nurse bees extending throughout the day. Since the time actually spent in the cell is so great and since the time occupied in inspection and in passing from cell to cell is considerable, in the absence of detailed investigation of the efficiency of the individual nurse bee one may only conclude that a single nurse bee is able to care for but a few larvæ.

In the case of the bumblebee the queen is able to rear 6 to 16 larvæ, varying somewhat with the species. The ant queen rears 12 to 15 larvæ, but in this case, as in the case of the bumblebee, the first brood is composed of quite small individuals. Those of the bumblebee are often not much larger than house flies. All worker honeybees are approximately of the same size, and in case supplies are so low that it is impossible to feed all the larvæ a sufficient amount of food to

bring them to normal size, some of the eggs, or even some of the larvæ are removed so that the remaining ones may be sufficiently fed.

To gain some idea of the immensity of the task of rearing a single larva it is necessary to refer to Table 6. Averaging the results found for the eggs and larvæ of all ages, it is seen that on an average more than 1,300 visits are made in 24 hours. On the last day before capping no less than 2,855 visits are made by the nurse bees to a single cell. On this last day before capping approximately 4¾ hours are spent by the nurse bees within the cell.

When these facts are considered, together with the time required for obtaining, preparing, and transporting the food, and the time required for capping the cells, it is evident that the rearing of brood constitutes a considerable burden to the working forces of the colony, doubtless reducing the field work and also other inside labors. It follows, therefore, that any considerable brood-rearing during the main honey flow must reduce materially the surplus honey procured. Not only is the surplus honey cut down because of the reduction in the number of field workers and comb builders, but honey which is brought in is lost, since it is fed to larvæ which usually develop too late to aid in the gathering of a crop.

The foregoing statements are substantiated in practical beekeeping by the well-established fact that a newly hived swarm gathers honey and builds comb more rapidly than an equally strong colony which has not swarmed. The reason for this is now clear. All members of a swarm may be either field workers or comb builders, while at first none of the nectar brought from the field is fed to brood, all of it being stored or consumed by adult bees. Similar results are obtained by confining the queen to a single brood chamber just before the honey-flow, since this somewhat limits the queen in egg-laying and reduces the amount of brood to be cared for during the honey-flow. Caging the queen has a similar effect, although this introduces other factors which may reduce the amount of surplus honey that might be obtained under this system.[3]

SUMMARY.

The attention given eggs and larvæ of the honeybee by the nurse bees consists in visits to the cells for purposes of inspection and for work or nursing carried on within the cell.

The number of such visits averages about 1,300 per day during the eight days from the time the egg is laid till the fully grown larva is sealed within the cell.

The elaborated food on which larvæ feed during about the first two days of the larval period is practically all placed in the cell with the newly-hatched larva soon after hatching. This is mass feeding.

Soon after the second day another kind of food is supplied to the worker larva. This food contains considerable undigested pollen and is fed at approximately the same rate at which it is consumed by the larva.

The fact that the method of feeding the worker larva is changed, for no apparent reason, after the second day, together with the excessive amount of time spent in visits of nurse bees to the older worker larvæ, suggests that there may be here a reciprocal feeding

[3] Phillips, E. F. Beekeeping. A discussion of the honeybee and of the production of honey, 457 p., 190 fig., front. New York, 1915. [See p. 282.]

between the nurse bees and the older worker larvæ, as has been observed in related insects, such as ants and wasps.

When a certain larva has received more than the average amount of nursing for larvæ of its age during one observation period, less than the average amount of nursing is given it during the following period. A conspicuous lack of nursing in one period is usually followed by more than average nursing in a subsequent period.

Over 10,000 visits are made to each developed individual bee during the eight days from the time the egg is laid until the cell is capped. During this same period a considerable amount of time is spent by the nurse bees actually within the cell. The time thus spent during the last day before capping is nearly $4\frac{3}{4}$ hours. A consideration of these facts, together with the time required for procuring, elaborating, and transporting the food to the cells, and also the time required for capping the cells, leads one to conclude that the number of bees engaged in nursing must be very large.

Beekeepers have recognized the great cost in honey and labor of the rearing of brood. They have, of course, recognized the desirability of rearing large amounts of brood before the honey-flow, but they also recognize the desirability of a reduction in brood-rearing after the honey-flow begins. They have to some extent accomplished the latter object by the removal of brood, by the caging of the queen, or by the reduction of the space available for egg-laying by the queen, these manipulations also accomplishing other purposes needful in certain phases of beekeeping (swarm control, comb-honey production, etc.). While these manipulations serve the purposes for which they are intended, they often introduce other factors which act adversely on the nectar gathering of the colony. One may not therefore from single facts regarding the excessive labor cost of brood-rearing recommend any special manipulations of the colony for the purpose of increasing the total honey crop, without a study of all the factors involved.

TABLE 5.—*Data obtained from observations of visits of nurse bees to cells containing eggs and larvæ.*

VISITS TO CELLS CONTAINING EGGS.

Designation.	Number of visits per period of 10 minutes.				Time spent in nursing[1] (seconds).	
	Inspection, Type A.	Inspection, Type B.	Nursing.[1]	Total.	Time spent in individual visits.	Total time spent per 10-minute period.
					Seconds.	*Seconds.*
Egg a	2	3	1	6	2	2
Egg b	3	4	0	7	0	0
Egg c	0	2	2	4	3, 19	22
Egg d	2	10	4	16	2, 3, 8, 4	17
Egg e	7	0	0	7	0	0
Egg f	5	0	1	6	5	5
Egg g	0	3	0	3	0	0
Egg h	1	2	0	3	0	0
Egg i	0	3	1	4	9	9
Egg j	0	3	3	6	4, 8, 2	14
Egg k	0	1	3	4	4, 4, 2	10
Egg l	1	2	2	5	2, 8	10
Egg m	1	3	0	4	0	0
Egg n	1	6	1	8	2	2
Average	1.64	3.0	1.29	5.93	5.06	6.50

[1] Under this heading are given visits of two seconds or more. There is no actual giving of food to the egg.

TABLE 5.—*Data obtained from observations of visits of nurse bees, etc.*—Contd.

VISITS TO CELLS CONTAINING LARVÆ ONE DAY AFTER HATCHING.

Designation.	Number of visits per period of 10 minutes.				Time spent in nursing (seconds).	
	Inspection, Type A.	Inspection, Type B.	Nursing.	Total.	Time spent in individual visits.	Total time spent per 10-minute period.
					Seconds.	*Seconds.*
Larva a	0	5	2	7	14, 29	43
Larva b	2	5	0	7	0	0
Larva c	3	4	1	8	2	2
Larva d	0	2	3	5	4, 20, 4	28
Larva e	2	3	3	8	2, 4, 4	10
Larva f	2	1	3	6	18, 8, 11	37
Larva g	0	8	2	10	2, 2	4
Larva h	0	4	2	6	13, 70	83
Larva i	0	0	1	1	2	2
Larva j	0	6	3	9	4, 2, 4	10
Larva k	0	6	0	6	0	0
Larva l	0	3	1	4	7	7
Larva m	0	3	1	4	60	60
Larva n	2	5	1	8	3	3
Larva o	0	4	3	7	7, 3, 12	22
Average	0.73	3.93	1.74	6.40	12.00	20.73

VISITS TO CELLS CONTAINING LARVÆ TWO DAYS AFTER HATCHING.

Larva a	0	5	1	6	2	2
Larva b	1	5	1	7	4	4
Larva c	1	3	2	6	3, 3	6
Larva d	1	2	3	6	3, 5, 2	10
Larva e	0	1	1	2	2	2
Larva f	0	5	0	5	0	0
Larva g	0	6	1	7	5	5
Larva h	0	4	2	6	2, 2	4
Larva i	0	3	0	3	0	0
Larva j	0	3	1	4	5	5
Larva k	2	0	1	3	2	2
Larva l	1	8	5	14	4, 8, 4, 12, 3	31
Larva m	0	4	3	7	2, 3, 4	9
Larva n	1	3	1	5	3	3
Average	0.50	3.71	1.57	5.79	3.77	5.93

VISITS TO CELLS CONTAINING LARVÆ THREE DAYS AFTER HATCHING.

Larva a	5	10	3	18	2, 5, 3	10
Larva b	7	5	0	12	0	0
Larva c	1	8	6	15	2, 3, 4, 3, 2, 4	18
Larva d	0	7	0	7	0	0
Larva e	0	6	2	8	36, 3	39
Larva f	0	3	0	3	0	0
Larva g	2	2	2	6	6, 8	14
Larva h	0	2	1	3	2	2
Larva i	2	3	1	6	3	3
Larva j	2	3	0	5	0	0
Larva k	0	4	4	8	7, 2, 2, 33	44
Larva l	1	4	1	6	7	7
Average	1.67	4.75	1.67	8.08	6.85	11.42

VISITS TO CELLS CONTAINING LARVÆ FOUR DAYS AFTER HATCHING.

Larva a	3	6	10	19	4, 3, 2, 5, 3, 2, 3, 2, 3, 30.	57
Larva b	5	17	10	32	4, 2, 4, 4, 2, 2, 2, 4, 2, 3.	29
Larva c	6	9	3	18	8, 5, 2	15
Larva d	3	3	5	11	13, 2, 2, 3, 5	25
Larva e	0	4	8	12	10, 7, 8, 8, 3, 5, 23, 8.	72
Larva f	0	6	1	7	3	3
Larva g	0	13	4	17	13, 12, 2, 3	30
Larva h	0	8	5	13	2, 13, 2, 3, 13	33
Larva i	0	7	7	14	2, 42, 3, 4, 8, 2, 4	65
Larva j	1	10	4	15	27, 2, 8, 30	67
Larva k	0	5	1	6	3	3

TABLE 5.—*Data obtained from observations of visits of nurse bees, etc.*—Contd.

VISITS TO CELLS CONTAINING LARVÆ FOUR DAYS AFTER HATCHING—Contd.

Designation.	Number of visits per period of 10 minutes.				Time spent in nursing (seconds).	
	Inspection, Type A.	Inspection, Type B.	Nursing.	Total.	Time spent in individual visits.	Total time spent per 10-minute period.
					Seconds.	*Seconds.*
Larva l	0	4	5	9	5, 2, 4, 2, 24	37
Larva m	0	8	8	16	3, 4, 2, 5, 4, 2, 6, 62.	88
Larva n	0	5	7	12	20, 5, 3, 2, 5, 11, 2	48
Larva o	0	11	5	16	5, 4, 25, 7, 2	43
Average	1.20	7.73	5.54	14.47	7.41	41

VISITS TO CELLS CONTAINING LARVÆ FIVE DAYS AFTER HATCHING.

Designation.	Inspection, Type A.	Inspection, Type B.	Nursing.	Total.	Time spent in individual visits.	Total time spent per 10-minute period.
Larva a	2	12	15	29	10, 2, 4, 3, 18, 3, 7, 18, 4, 11, 3, 3, 3, 2, 4.	95
Larva b	3	7	17	27	3, 25, 8, 8, 2, 7, 8, 7, 9, 2, 2, 20, 40, 2, 3, 6, 2.	154
Larva c	2	9	8	19	2, 2, 2, 5, 3, 2, 2, 2.	20
Larva d	0	14	6	20	58, 62, 14, 4, 110, 2.	250
Larva e	0	8	3	11	2, 2, 6	10
Larva f	0	16	7	23	2, 3, 2, 63, 2, 7, 3	82
Larva g	0	12	2	14	60, 10	70
Larva h	0	7	14	21	17, 23, 5, 15, 10, 70, 2, 7, 25, 45, 7, 15, 35, 15.	291
Larva i	0	11	10	21	60, 3, 2, 2, 4, 5, 6, 5, 7, 16.	110
Larva j	0	9	10	19	7, 2, 4, 3, 6, 3, 3, 3, 2, 2.	35
Larva k	0	10	5	15	3, 10, 9, 2, 45	69
Larva l	0	8	11	19	7, 15, 35, 3, 7, 40, 35, 35, 15, 15, 24.	231
Average	0.58	10.25	9.0	19.83	13.12	118.08

TABLE 6.—*Summary (from Table 5) of the number of visits of all kinds, each record being the total for an individual egg or larva for a 10-minute period.*

Age.	Number of visits of all kinds by nurse bees.															Average per period.
Egg	6	7	4	16	7	6	3	3	4	6	4	5	4	8	....	5.93
1-day larva	7	7	8	5	8	6	10	6	1	9	6	4	4	8	7	6.40
2-day larva	6	7	6	6	2	5	7	6	3	4	3	14	7	5	....	5.79
3-day larva	18	12	15	7	8	3	6	3	6	5	8	6	....	....	....	8.08
4-day larva	19	32	18	11	12	7	17	13	14	15	6	9	16	12	16	14.47
5-day larva	29	27	19	20	11	23	14	21	21	19	15	19	....	....	....	19.83

TABLE 7.—*Summary (from Table 5) of the time spent in nursing, each record being the total for an individual egg or larva for a 10-minute period.*

Age.	Time spent in nursing (seconds).															Average per period.	Average per visit.
Egg	2	0	22	17	0	5	0	0	9	14	10	10	0	2	....	6.50	5.06
1-day larva	43	0	2	28	10	37	4	83	2	10	0	7	60	3	22	20.73	12.00
2-day larva	2	4	6	10	2	0	5	4	0	5	2	31	9	3	....	5.93	3.77
3-day larva	10	0	18	0	39	0	14	2	3	0	44	7	....	....	....	11.42	6.85
4-day larva	57	29	15	25	72	3	30	33	65	67	3	37	88	48	43	41.00	7.41
5-day larva	95	154	20	250	10	82	70	291	110	35	69	231	....	....	....	118.08	13.12

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

February 18, 1924.

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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN NO. 1223

Washington, D. C. ▼ July 10, 1924

THE EUROPEAN ELM SCALE IN THE WEST.[1]

By Frank B. Herbert,[2] *Scientific Assistant, Forest Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

The European elm scale, *Gossyparia spuria* (Modeer), has long been known in Europe and the Eastern United States as a serious enemy of the elm. It was first discovered in the West in 1893, when E. M. Ehrhorn found it infesting elms on the Stanford University campus, Palo Alto, Calif. Prompt measures of eradication were attempted, but were not entirely successful. Since that time it has spread from this or other sources until it is now quite widely distributed throughout the West. It is becoming of considerable importance as a shade-tree pest owing to its distribution and to its particularly aggressive habits in newly infested localities.

IMPORTANCE.

The elm is probably the most popular shade tree in America. It attains good size, produces a luxurious amount of green foliage, and is planted throughout the United States and elsewhere in dooryards, along streets, and in parks for shade and ornament. In the East

[1] Acknowledgments are due to Dr. A. D. Hopkins, Forest Entomologist; H. E. Burke, Specialist in Forest Entomology; Harold Morrison, Coccidologist; and others, for helpful suggestions and observations; to W. S. Fisher, Specialist in Forest Coleoptera, for identification of the coccinellid predators; to S. B. Doten, Director and Entomologist of the Nevada Agricultural Experiment Station, and to Frank N. Wallace, State Entomologist of Indiana, for the use of a number of illustrations used in this publication.

[2] Resigned June 30, 1920.

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the native elm also produces wood which is particularly valuable in the making of vehicles, baskets, crating, etc.

The European elm scale infests all species of elm, having become such a very disagreeable and harmful pest that in many eastern localities these trees are no longer recommended for planting. In the West the scale insect is not so widely distributed, nor are many of its eastern associates present, so that in spite of the elm scale the tree is still recognized as one of the best for shade.

Fortunately, the scale in America infests only elms and is not a pest on fruit or other shade trees, as are many of the aggressive scale insects.

HISTORY.

This insect was first noted in the United States in 1884, when Charles Fremd found it infesting elm trees in his nursery at Rye, Westchester County, N. Y. It had undoubtedly been imported from Europe, where it has been known for nearly 200 years. It was next reported by Professor Comstock from New York City, where he had found it rather abundant in the winter of 1886–7. A few months later John G. Jack sent specimens to the United States Bureau of Entomology from slippery elm growing at Cambridge, Mass. In 1888 it was found at Washington, D. C., infesting elms on the grounds of the Department of Agriculture and also in two localities on the streets of the city.

Up to this time it had not been positively identified, but the next year Dr. L. O. Howard made a thorough study of the insect and identified it as the European elm scale (*10*).[3]

A few years later this scale insect was found to have invaded the western part of the United States. In 1894, Alexander Craw (*2*), of the California State Board of Horticulture, reported that during the previous season E. M. Ehrhorn had noted the European elm scale upon elms at Stanford University, California. The next year Mr. Hillman, entomologist of Nevada, reported it from Reno, Nev., and in 1906 A. L. Melander (*16*), entomologist of Washington, stated that it had been in Spokane, Wash., for several years.

From time to time it has been reported from one State or another until it is now known to occur in 27 States besides the District of Columbia.

SYNONYMY.

As early as 1738 this scale was known in Europe, at which time Reaumur (*18*) figured the female in all its stages and gave its natural history, but failed to give it a name except that of "progallinsecte" of the elm.

The first name given to it was *Coccus ulmi* by Linnaeus (*14, p. 265*) in 1761. In 1875, Signoret (*19, p. 21*) removed this insect from the genus Coccus and erected a new genus, Gossyparia, with *ulmi* as the type. The specific name *ulmi* was retained until recently, when it was discovered that it rightfully belonged to another insect named *Coccus ulmi* Linnaeus (*13, p. 455*) in 1758, since removed to the genus Lepidosaphes. Consequently the next specific name used for the European elm scale, *spurius*, applied to it in 1778 by Modeer

[3] Numbers in parentheses (*italic*) refer to Literature cited, p. 18.

(*17*), was adopted, so that now the proper name is considered by most entomologists to be *Gossyparia spuria* (Modeer).

The latest change has been by the European coccidologist Lindinger (*12, p. 331*), who put this species into Eriococcus, where the writer considers that it rightfully belongs. No move has been made toward accepting this name in the United States so far, however, so that the writer does not feel inclined to use it in this paper.

The two genera, Gossyparia and Eriococcus, are separable only from the fact that the adult female of the former secrets a semi-cocoon, while the latter entirely covers itself with a cottony cocoon. This means that *Gossyparia spuria* lacks wax-secreting glands on the dorsum, which can hardly be considered a generic character. If the name *Ericoccus spurius* is accepted, then the genus Gossyparia will become a synonym of Eriococcus, as *spuria* is the type of that genus.

From time to time this insect has been referred to under the following names: *Coccus ulmi*, *C. spurius*, *C. laniger*, *C. gramuntii*, *Chermes ulmi*, *Nidularia lanigera*, *N. gramuntii*, *Gossyparia ulmi*, *G. gramuntii*, *G. spuria*, and finally *Eriococcus spurius.*

DISTRIBUTION AND SPREAD.

DISTRIBUTION.

This common pest is widely distributed, not only in North America but also in Europe, where it reaches from Spain to Turkey and as far north as Norway. Kuwana (*11*) has also reported it from the province of Shinano, Japan. The writer has seen specimens from there collected by Mr. Kuwana, however, which undoubtedly are not *Gossyparia spuria*, but are some rather closely related species. The writer is informed that Mr. Kuwana is now of the same opinion. Instead of being encircled with fringe of wax, the body of the mature female is entirely covered with it—a character which should place this species in the genus Eriococcus.

In America the scale is found both in Canada, where it has been reported from the provinces of Ontario and Quebec, and in the United States, where it occurs in 27 States and the District of Columbia. It is still spreading, for occasionally a new State is added to the list. The scale is known to occur in the following Eastern, Central, and Southern States: Maine, New Hamshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, West Virginia, Ohio, Michigan, Wisconsin, Indiana, Illinois, Iowa, Missouri, Alabama and Louisiana.

In the west the scale occurs in the following States: Colorado, Utah, Nevada, Idaho, Washington, and California. (Fig. 1.) Its distribution in these States is more or less limited. In Colorado, C. P. Gillette, State entomologist, reports that it has been doing damage for some time in the city of Denver. George M. List (*15*), his chief deputy, has since reported it from Golden and from near Fruita, Mesa County. W. W. Henderson, entomologist of the Utah Agricultural Experiment Station, states that to his personal knowledge it exists in isolated places about 100 miles north and south

of Salt Lake City and in the region between these two extremes, where it occasionally does severe damage. In Nevada it is confined to a limited area in the west-central part of the State, extending from Carson City to Reno, according to S. B. Doten (*3*, *5*), director of the Nevada Agricultural Experiment Station, and from the writer's personal observations. A. L. Melander (*16*), entomologist of the Washington Agricultural Experiment Station, reports that he has not found it anywhere in the State of Washington, except at Spokane, where it has been for 15 years or more. The files of the Bureau of Entomology also contain records of this insect occurring at Coeur d' Alene and Boise, Idaho.

In California, the insect is somewhat more widespread, occuring in a number of localities in the northern and central portions of the State. It has been found in or near the following towns: Ukiah, San Rafael, Colusa, Woodland, Davis, Sacramento, Stockton, Modesto, Oakdale, Woodside, Redwood City, Palo Alto, Stanford University, Mayfield, Mountain View, Los Altos, Santa Clara, College Park, San Jose, Milpitas, Edenvale, Los Gatos, and Saratoga.

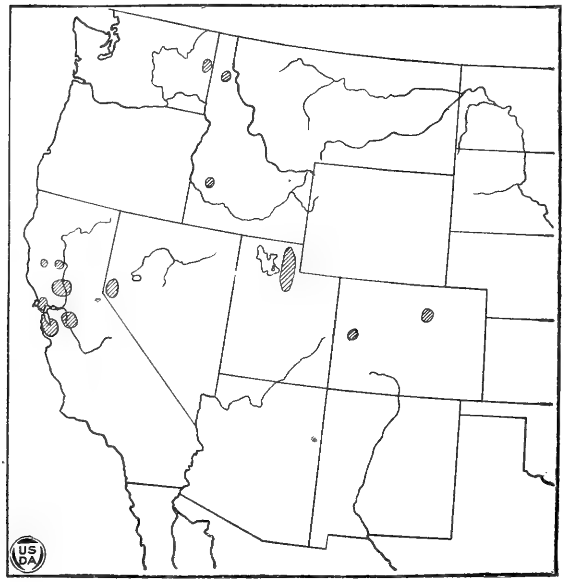

FIG. 1.—Known distribution of European elm scale in the West.

Additional localities in the United States and Canada have been recorded by Albert Hartzell (*8*).

SPREAD.

The elm scale was in all probability brought to America from Europe on young elm trees. The shipment of elm stock from infested nurseries to various parts of the United States has also been the cause of its being scattered over such a wide territory.

In these infested localities the scale has spread from tree to tree by several agencies. Birds, such as English sparrows, which are to be found in large numbers in the shade trees of almost any town, probably carry the young crawling scales for considerable distances on their feet. During the fall infested leaves drop to the ground and are blown for some distance by the wind. A certain percentage of these larvæ happen to find themselves at the base of an elm tree and crawl up to start a new infestation. The European elm scale has been seen spreading in this manner by both Professor Doten and the writer. The Argentine (*Iridomyrmex humilis* Mayr) and

other ants are known to transport scale insects from one tree to another in order to increase their food supply, and this method of transportation probably applies to this species as well as to others, since it is usually attended by a great many ants. Elms are nearly always planted so close that some of their branches interlace, enabling the larvæ to crawl at will from one tree to another. Thus it is not long before the European elm scale has thoroughly established itself upon most of the elms in a locality.

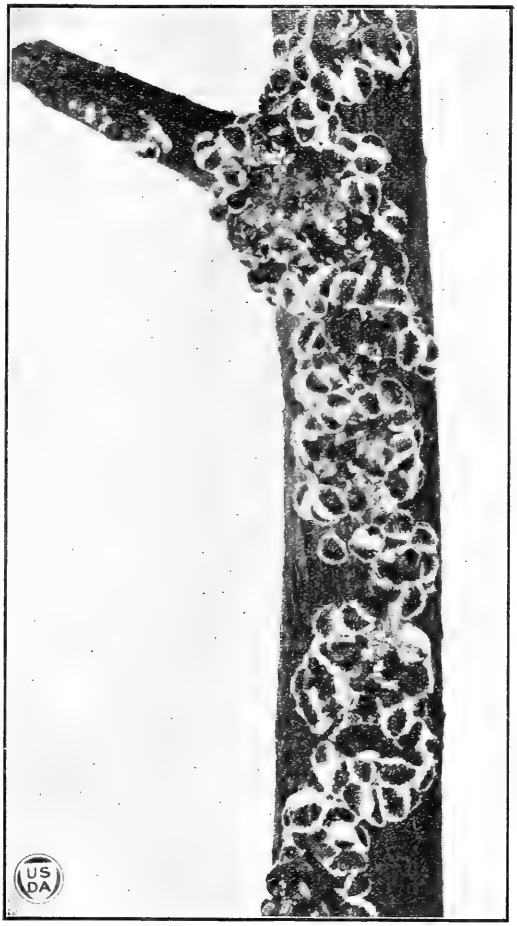

FIG. 2.—Adult females of European elm scale on elm branch. Slightly enlarged. (Wallace.)

INJURY.

Thousands of these scale insects sucking the plant juices from the leaves, twigs, and branches (figs. 2, 3) cause considerable injury to elm trees. Their effect upon the elm is shown by yellowing and premature dropping of the leaves, stunting of growth, and dying twigs, branches, and entire trees. Their injury is most apparent on young trees, which occasionally they kill. Mature trees are seldom killed.

A less serious trouble is the production of a considerable amount of honeydew, which covers the leaves, twigs, and branches, making them black and sticky. It also drops on the street and sidewalk, making the pavement slippery and dangerous to passing vehicles, besides having an unpleasant appearance and odor. Many disagreeable insects are attracted by the honeydew.

In some sections the American elm is reported as the favorite host of the European elm scale, while in other localities the English, Camperdown, or slippery elm is reported to be the favorite. The American and Camperdown elms seem to be preferred by it in California. Probably the degree of infestation depends upon the condition of the tree more than upon any other factor.

Trees which have been attacked for a number of years by this insect, if they do not die, finally seem to develop a certain amount of resistance to its injury. The history of this scale insect throughout North America has been much the same. It causes much concern to the owners of shade trees for a number of years after making its first appearance, and then seems slowly to lose its grip upon the trees until it causes a much smaller amount of damage. This is especially true in sections of the Eastern States and Canada, where less attention than formerly is now paid to this once dreaded insect.

FOOD PLANTS.

The recorded food plants of the European elm scale in the United States are English elm (*Ulmus campestris*), Scotch or Wych elm (*U. scabra*), European species, and white or American elm (*U. americana*), cork elm (*U. racemosa*), and slippery elm (*U. fulva*), American species, and their varieties. Probably all species of elms are subject to attack by this insect, although some have not yet been recorded as host to it.[4]

In 1895 Lintner, then State entomologist of New York, collected immature specimens of a scale insect on willow at Loudonville, N. Y., which were determined at that time as the European elm scale. This determination has since been corrected and those specimens have now been identified as a species of Eriococcus.

Signoret (*19*, *p. 21*), a French entomologist, has stated that he collected *Gossyparia spuria* on alder in France. Lindinger (*12*, *p. 54*, *64*, *122*, *159*, *338*), also a European entomologist, gives the following hosts in addition to elm: *Acer* sp., *Alnus* sp. (very probably Signoret's record), *Corylus avellana*, *Fraxinus excelsior*, and *Viscum album*, all European records. From the fact that the European elm scale has not been found on any of these hosts in America, the writer is inclined to believe that some related species has been confused with it. At any rate there are no records of the European elm scale occurring on anything except elms in America. The writer has seen both alders and willows growing with their branches interlaced with those of infested elms, yet not a scale could be found on either of them. One specimen of *Zelkova acuminata*, which belongs to the elm family (Ulmaceae), has been seen growing near a large number of infested elms, but no infestation was apparent upon it.

DESCRIPTIONS.

EGG (PL. I, A).

Oval in outline, twice as long as wide, 0.36 by 0.19 millimeter. Color bright yellow; surface smooth and shiny. Eyes of larva visible as two black spots through the egg membrane.

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[4] Aside from the European elm scale the principal insect pests of the elm in the West are the carpenter worm, *Prionoxystus robiniae* Peck, which bores into the trunks and main limbs, often killing large branches and occasionally whole trees; an aphid, *Myzocallis ulmifolii* Monell, and a leafhopper, *Empoa ulmi* L., both of which suck the plant juice from the elm leaves and produce an abundance of honeydew. They are sometimes worse than the elm scale in this respect.

The elm leaf-beetle, *Galerucella luteola* Müll., is probably the worst enemy of the elm in the East, where it defoliates a great number of trees every year. It has also been introduced into the West, having been reported several years ago from Portland, Oreg. This has not yet become a serious pest in the West, but may in the near future.

LARVÆ.

First Stage (Pl. I, *B*).

Color bright yellow soon after hatching. Length 0.45 millimeter; width 0.19 millimeter. Of an elongate oval form, rounded anteriorly and tapering posteriorly to a pair of pointed processes, each bearing one long and several short setæ. Anal ring, occurring between these processes or lobes, with six setæ or hairs. Legs rather stout, with short tibiæ. Usual two pairs of thoracic spiracles present. A single row of blunt spines on the lateral margin of larva and a double row extending down the back, some reduced to rudiments. Also

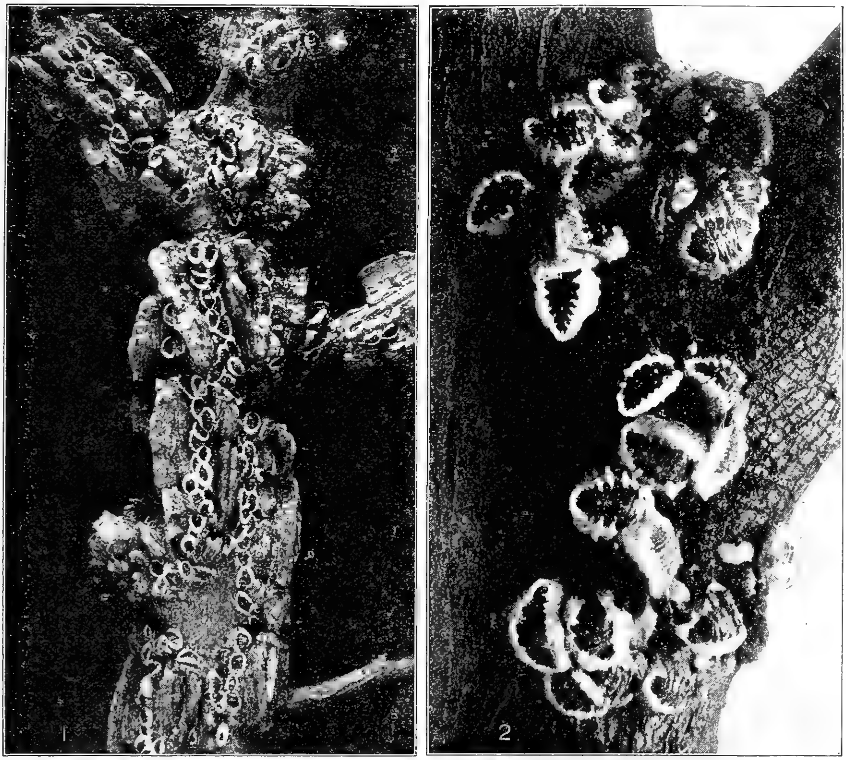


Fig. 3.—Females of the European elm scale: *1*, Dead females in winter on corky elm (natural size); *2*, living females in summer (enlarged about 4 diameters). (Doten.)

six extra spines on head and a number of very small spines on dorsum. Antennæ (Pl. III, *A*) rather stout and 6-segmented, sixth segment longest, fourth and fifth subequal and shortest, each segment bearing several hairs.

Second Stage (Pl. I, *C*).

Full-grown second-stage larva reddish brown in color. (In life of a gray appearance, due to the protruding wax.) Body oval in outline, rounded anteriorly and rather pointed posteriorly, about 1.1 millimeters long and 0.6 millimeter wide. Eyes situated near margin of body behind antennæ. Legs rather long and slender. Two pairs of thoracic spiracles present. Anal ring compound, bearing six setæ and situated between two prominent pointed anal lobes, each bearing a long slender spine on its tip, also several shorter spines on lobes. Entire dorsum covered with stout blunt spines and arranged more or less in two rows on each abdominal segment. Few small spines on venter.

In this stage one is able to distinguish the difference in sexes by the number of antennal segments. Antennæ of male larva 7-segmented, first segment broadest and seventh longest (Pl. III, *B*). Female larva with 6-segmented antennæ, quite similar to those of male, except that third and fourth segments have been replaced by one long segment, practically equalling the other two (Pl. III, *C*).

Both sexes have pores of the quinquelocular type (Pl. III, *E*) on the venter, but only the male larva has large circular pores on the dorsum and margin of the venter. These circular pores communicate with internal cylindrical ducts, which bear cup-shaped depressions on their inner ends (Pl. III, *G*), and are presumably the ones used in secreting the wax to form the pupal cocoon.

Adult or Third-Stage Female (Pl. I, *D*, *E*).

Female dull red-brown or green-brown after molting, elliptical in outline, later becoming oval and at the same time forming a waxy fringe about the margin of the body. Upon becoming engorged with eggs the adult female attains a length of 2.1 millimeters and a width of 1.3 millimeters. Antennæ (Pl. III, *D*) distinctly 7-segmented, third and fourth segments longest, fifth and sixth shortest. Previous writers have not always agreed upon the number of antennal segments possessed by the adult female. In some species the number is not constant; however, all western specimens examined possessed 7-segmented antennæ.

Usual coccid mouth parts and two pairs of thoracic spiracles present. Legs (Pl. III, *I*) rather long and slender. Anal ring compound, bearing eight setæ, and situated between two prominent lobes (Pl. III, *H*), each bearing three dorsal spines and one terminal and two ventral setæ, also a number of nodules which are particularly prominent and abundant on the inner surface. Entire dorsum covered with stout blunt spines, arranged as in preceding stage. Small slender spines and pores of quinquelocular type (Pl. III, *E*) on venter. Large circular pores (Pl. III, *G*) occur on dorsum and margin of body, being more plentiful on latter. These communicate with internal cylindrical ducts which bear cup-shaped depressions on their inner ends. There are also a few very small circular pores on the margin of the body communicating with small, slender, internal tubular ducts.

MALE PREPUPA (PL. II, A).

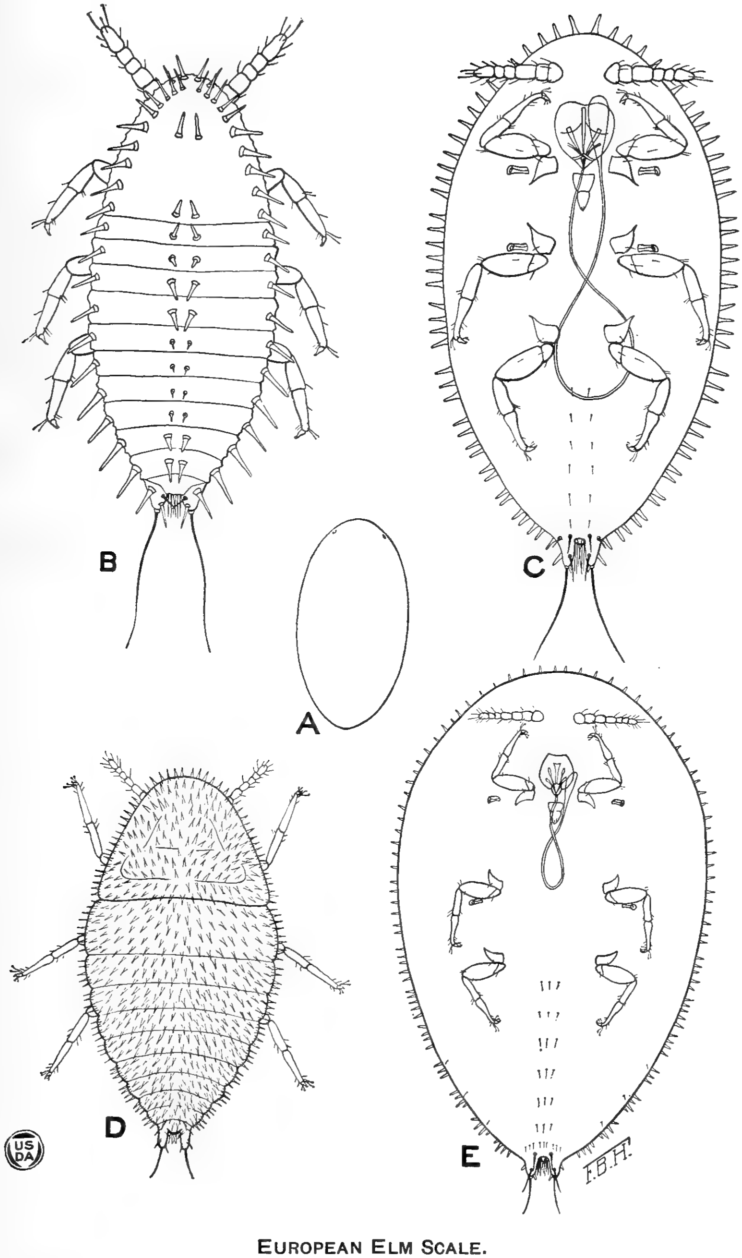
The second-stage male larva after forming a cocoon molts to a prepupa, which is the first dormant stage of the male. Color brownish red. Length 1 millimeter, and width about 0.5 millimeter. Oval in outline with head somewhat pointed. Apex of abdomen 3-lobed, a slender seta occurring on each outer lobe. Antennæ and legs not now long and slender, but short, thick, and immovable. Antennæ indistinctly 10-segmented. Very short wing pads present. No eyes visible and mouthparts lacking. Segmentation of body indistinct.

MALE PUPA (PL. II, B).

The second dormant stage of the male is also passed in the cocoon. This is a separate stage from the prepupa, a molt having taken place in between. Brownish red in color, oval in outline, slightly longer (1.1 millimeter), and more slender than prepupa. Top of head more rounded and tip of abdomen more distinctly three-lobed, central lobe larger and more pointed. Antennæ large and heavy, distinctly 10-segmented, reaching to base of wing pads. Wing pads larger, reaching to middle femora or beyond. Legs more distinctly segmented, longer and more slender, anterior pair folded over "face." Body more distinctly segmented; mouth parts lacking.

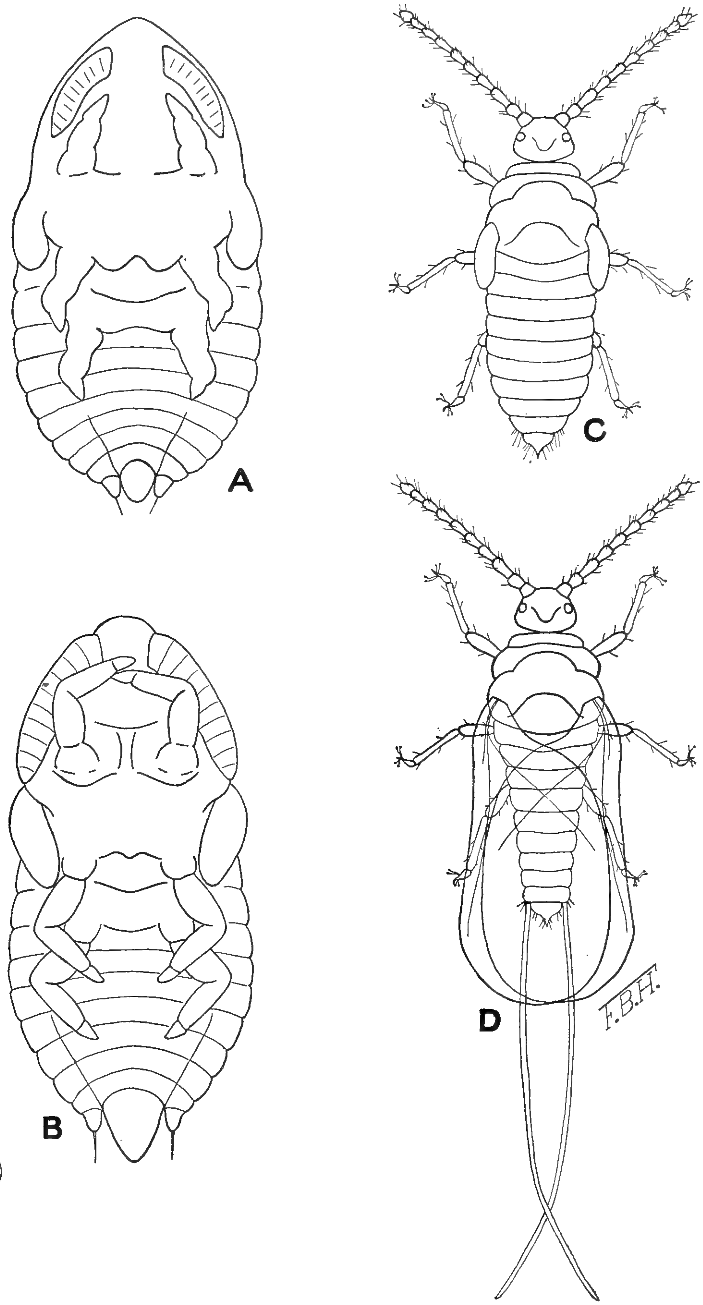
ADULT MALE.

Reddish brown in color and longer and more slender than pupa; 1.3 millimeters long and 0.4 millimeter wide. Head rounded, truncate between antennæ. Eyes black, with usual dorsal pair present and one ventral pair replacing mouth parts. Antennæ rather long and hairy, 10-segmented. Legs long and slender, tibia longer than femur. Caudal end 3-lobed, middle lobe large and pointed, bearing the genital organs; all three lobes bearing a number of setæ. Two large setæ on each outer lobe surrounded with a number



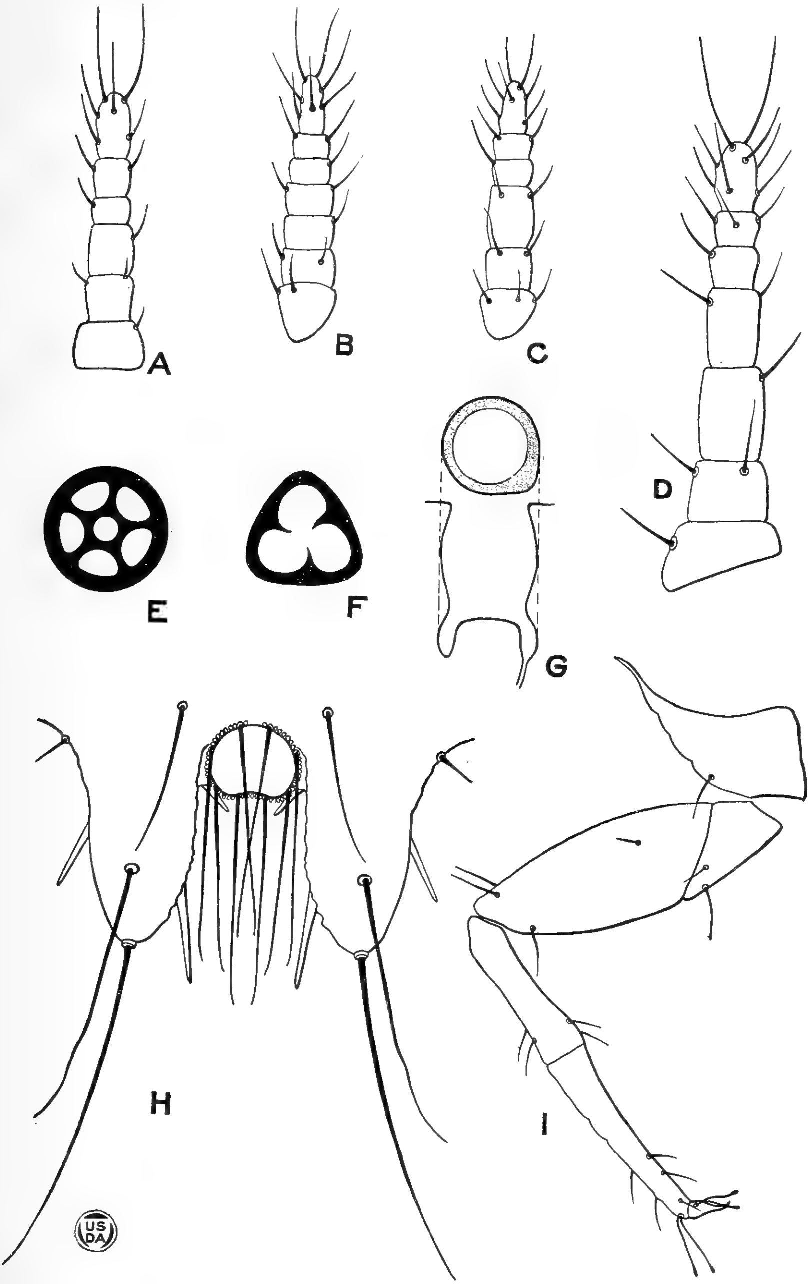
EUROPEAN ELM SCALE.

A, Egg. *B*, Dorsal view of first-stage larva. *C*, Ventral view of second-stage female larva. (Second-stage male larva is identical except for antennæ, which are 7-segmented.) *D*, Dorsal view of newly molted or virgin female. *E*, Ventral view of mature female.



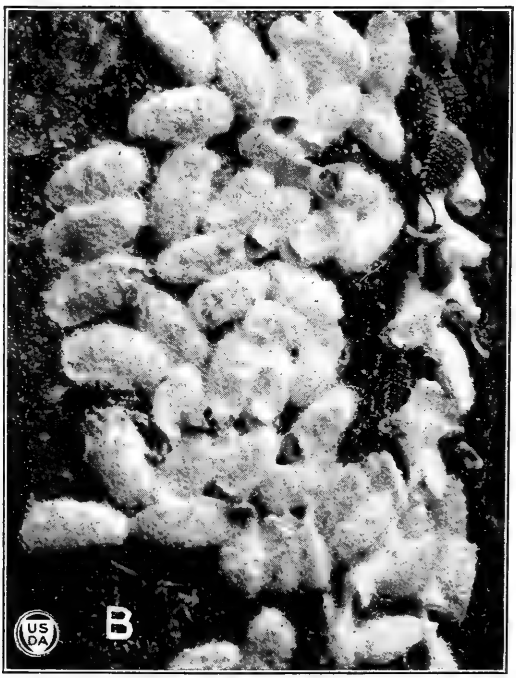
EUROPEAN ELM SCALE.

A, Male prepupa. *B*, Male pupa. *C*, Wingless male adult. *D*, Winged male adult.



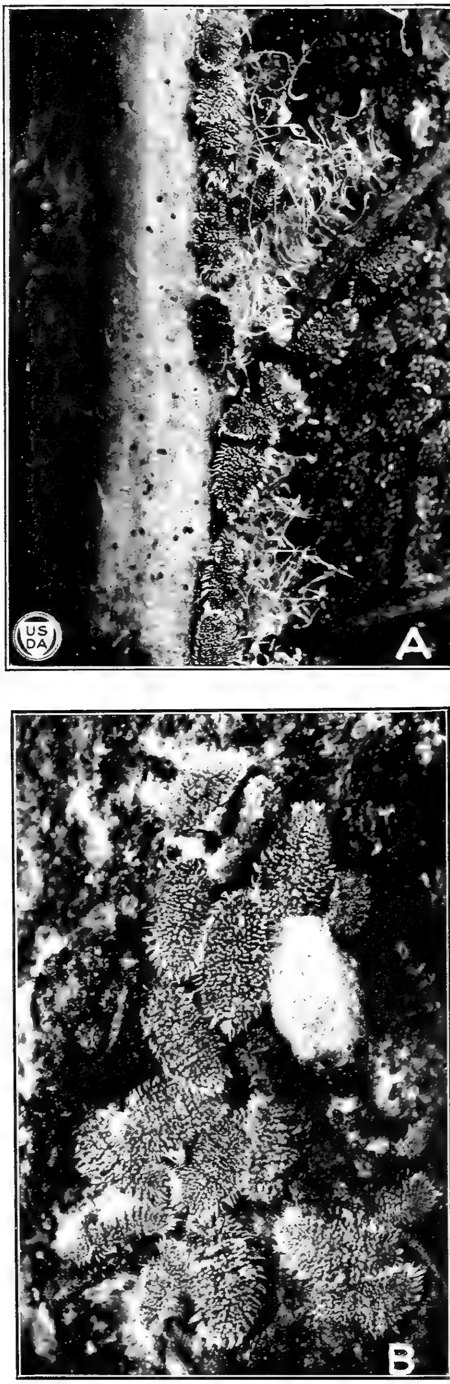
EUROPEAN ELM SCALE.

A, Antenna of first-stage larva. *B*, Antenna of second-stage male larva. *C*, Antenna of second-stage female larva. *D*, Antenna of adult female. *E*, Quinquelocular type of pore. *F*, Trilocular type of pore. *G*, Circular pore and cross-section of internal communicating duct. *H*, Ventral view of tip of abdomen of adult female. *I*, Leg of adult female.



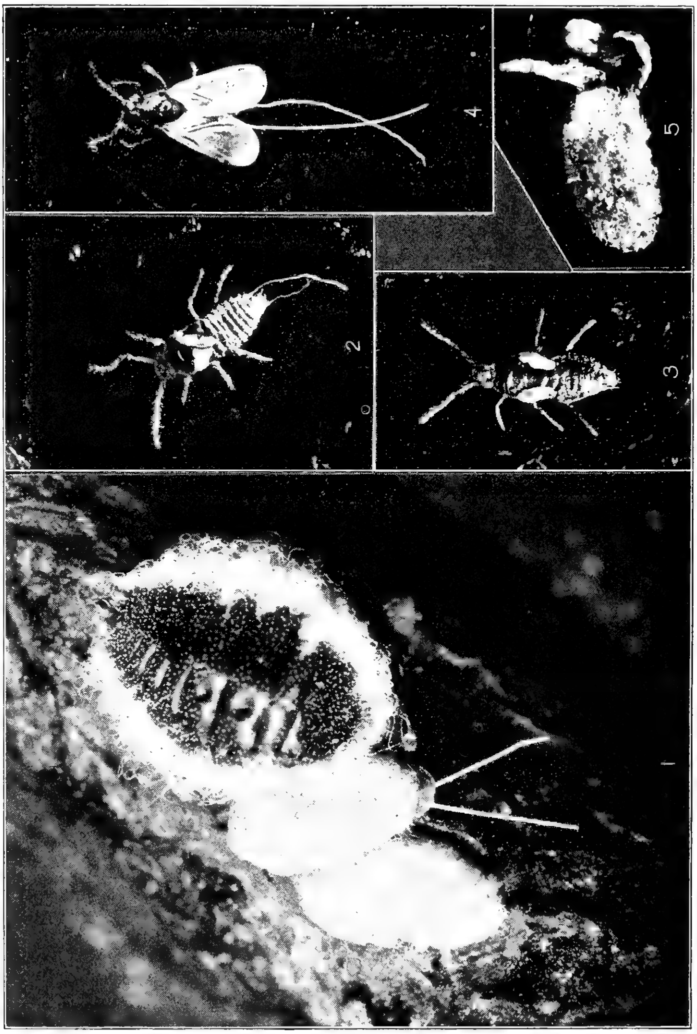
EUROPEAN ELM SCALE.

A, Larvæ in winter partly concealed in crack in elm (× 10).
B, Larvæ and male cocoons in early spring (× 16). (Doten.)



EUROPEAN ELM SCALE.

A, Larvæ in late summer along midrib on under surface of elm leaf (× 16). *B*, Male cocoons on elm bark (× 10). (Doten.)



EUROPEAN ELM SCALE.

1, Cocoon with protruding wings and anal filaments. *2* and *3*, Wingless males. *4*, Winged male. *5*, Cocoon, cast skins of larva and pupæ. (Doten.)

of trilocular pores (Pl. III, *F*). These are presumably what produce the wax filaments on some males.

There are two forms of the male, winged and wingless. The winged form (Pl. II, *D*) has full-sized wings folded over the dorsum when not in use, while the wingless form (Pl. II, *C*) has only short wing pads. The body of the wingless form is occasionally broader than that of the winged. There are, moreover, all grades between these two extremes, having all sizes of malformed wings. Two wax filaments, borne on the anal lobes, extend posteriorly and equal the length of the body in perfect males. These also vary in length, however, and may be present or entirely lacking on either the winged or wingless forms.

LIFE HISTORY AND HABITS.

In the spring after mating the female scales are found to contain a few eggs. By the time they have completed their semicocoons, however, they are well filled with eggs and have increased considerably in size.

OVIPOSITION.

The eggs remain in the body of the adult female until the embryos are about to hatch. As each embryo becomes fully developed the egg is expelled ventrally from near the tip of the abdomen. They are thus laid in a sort of pocket, being protected by the body of the mother and the surrounding fringe of wax.

Each female is capable of laying a large number of eggs. Adults examined on July 5, 1919, after having laid for some time, contained from 97 to 138 eggs. Professor Doten, of Nevada, reports having counted 60 to nearly 300 dead larvæ, which had been unable to escape from under different females. A drawing of the ovaries of an adult female by R. E. Snodgrass (*20, fig. 19*), would indicate a still larger number. He figures over 200 on one branch of the oviduct, making a total of approximately 425 eggs from one female. This would indicate that the rate of increase is quite large, yet not as great as that of many other scale insects.

The eggs are laid slowly, covering a considerable period of time, and only during the warm part of the day. One female observed laid 16 eggs in 5½ hours, or 1 about every 20 minutes. The larvæ hatch from these eggs about 40 minutes later and are ready to crawl away in another half hour.

It has several times been reported that the adult females give birth to living young. These misstatements are probably due to the fact that the eggs hatched very soon after deposition and were not seen by these observers.

LARVÆ.

Newly hatched larvæ are active and soon seek a place for attachment. Some attach themselves to twigs and branches, while a large majority of them migrate to the leaves, where they settle on both the upper and lower surfaces along the midribs, the pubescence of the leaf-veins affording them some protection. (Pl. V, *A*.) They remain in these positions until fall. By this time they are second-stage larvæ, having undergone their first molt about six weeks after hatching.

In the autumn, when the leaves begin to fade and fall, these larvæ move to more permanent places, locating in the crevices of the bark on the twigs and branches (Pl. IV, *A*) and clustering about the winter buds, where they spend the winter. Some of the larvæ fail to move from the leaves before these fall from the trees, and are carried considerable distances by the wind. Some of these die from starvation, while others crawl up the trunks of near-by trees to new feeding grounds.

The first-stage larvæ excrete very little wax, but the second-stage larvæ are well covered with sugary-appearing particles of it. This protects them in the winter from frost and rain and incidentally makes them immune to any mild form of spray material.

The larvæ remain in the second stage for from six to seven months, or from late summer to late winter or early spring. The male larvæ are the first to leave their winter quarters. In fact, some of them do not wait for winter to end, for on the first mild days in late January they begin to form their cocoons in which to pupate. They seem to be particularly fond of making their cocoons (Pl. IV, *B*) on dead twigs or branches, in the bark crevices, or near the crotches of living limbs. Their cocoons may even be found massed together in large white patches (Pl. V, *B*) on smooth exposed parts of the trunk or branches.

ACTIVITIES OF THE MALE.

The cocoon is made of waxy threads, secreted from the pores on the body of the larva. These are woven and twisted about until a definite covering has been formed. After completing the cocoon, which requires several days, the larva changes to a prepupa, which is the first dormant stage in the transformation from larva to adult. A definite molt takes place at this time, the cast skin being pushed out through a slit in the rear end of the cocoon.

A week or so later another molt occurs, this time to a true pupa, the second cast skin being pushed back out of the cocoon. (Pl. VI, *5*.) This stage occupies from one to two weeks, whereupon the pupa changes either to a winged (Pl. VI, *4*) or a wingless (Pl. VI, *2*, *3*) adult male. All the first pupæ to transform become wingless males, while all the last become winged males. During part of the intervening time both winged and wingless adults can be found, together with different forms between these two extremes. For instance, some males will have partly formed to nearly fully formed wings, while the wax anal filaments may vary from partly formed to full length or even be entirely lacking on either extreme. Temperature and humidity probably cause these variations. E. P. Felt (*7*), of New York, reports a definite period occurring between the appearance of the two forms of the adult male in the State. There is no such period in the West.

The wax filaments may be seen protruding from the cocoons for a day or so before the males emerge (Pl. VI, *1*), which they accomplish by backing out. They live only a few days, dying soon after they mate.

ACTIVITIES OF THE FEMALE.

The hibernating female larvæ begin their activities a little later than the male larvæ. In fact, most of them show no signs of activity until March, when they begin molting for the last time (Pl. IV, *B*). The white cast skins appear quite conspicuous on the bark. The newly molted or virgin females are smooth and of a dull brown or greenish-brown color. After mating they move about and settle down for the last time, most of them selecting the lower side of the larger limbs and branches. They soon take on a grayer appearance and begin to form waxy fringes of cotton or semicocoons about the margins of their bodies. By the middle of May they have about completed their semicocoons and are full grown, ready to begin oviposition. Egg laying lasts for several months, or until about the middle of August. During this time the females have slowly shriveled and die upon completing oviposition.

Soon after molting to the third stage the females begin excreting honeydew, and do not stop until egg laying is completed. This drops onto the foliage and the ground beneath, making the trees and ground very sticky. A black smut fungus grows in this sticky material, giving the foliage a black appearance which can be seen for great distances.

SEASONAL HISTORY.

There is only one generation a year of the European elm scale. The second-stage male and female larvæ are the forms hibernating. Late in January in the milder climates a few of the male larvæ start forming cocoons in which to pupate. These become more abundant during February and March. Adult males begin emerging from their cocoons in February, becoming more abundant in March and April. A few of the last to transform emerge in May.

The hibernating female larvæ molt for the last time in March and April, whereupon they move to a proper place for the summer and mate. They soon begin to increase considerably in size, at the same time forming waxy semicocoons about their bodies. Egg laying starts the last of May or the first of June and continues through June, July, and part of August. Having completed oviposition the females shrivel and die.

The eggs hatch in less than an hour after being deposited and the tiny yellow larvæ crawl about, some settling on the twigs and branches, but most of them settling along the midribs of the leaves. About the middle of July the first of these larvæ molt for the first time, becoming reddish brown and later gray from the sugary particles of wax which are secreted over the back. The last of the yellow larvæ molt early in September. These second-stage brown or gray larvæ are the overwintering forms, and are found mostly clustered about the winter buds and in the rough areas of the twigs and branches.

A definite relationship has been observed between the activity of the European elm scale and its host. As the events in the life cycle

of the elm are more evident than those of the scale insect, it is well to indicate this relationship, especially since the time of application of control measures often depends upon both. The tree and the insect awaken from hibernation at the same time. The females undergo their last molt while the fruit is forming on the tree. Most of them have attained a large size and are secreting their semi-cocoons when the fruit begins to fall from the tree. The semi-cocoons are completed by the time most of the leaves are full grown, and egg laying starts two or three weeks later. The second-stage larvæ migrate from the leaves back to the twigs and branches when the tree sap becomes sluggish and the leaves begin to yellow and fall.

NATURAL ENEMIES.

The insect enemies of the European elm scale are very scarce and play but a small part in its control. The first and only record of the rearing of a parasite from this scale in the United States was in 1898 by R. A. Cooley (*1*), who reared half a dozen specimens at Concord, Mass. These have never been described, but remain under the manuscript name of *Coccophagus gossypariae* Howard. The writer endeavored a number of times to obtain parasites from western material, but was unsuccessful. Either there are none in the West or they are so scarce that they do not figure in the control of this scale insect.

The predatory enemies of the European elm scale are somewhat more numerous, but even they can not be considered as important agencies in its control. The twice-stabbed lady-beetle, *Chilocorus bivulnerus* Mulsant, is the most common enemy of the European elm scale. Essig (*6, p. 119–120*) mentions that Dr. A. J. Cook reported this beetle as preying upon the scale insect at San Rafael, Calif. The writer also has observed beetles of this species feeding upon the body contents of adult females.

Both larvæ and beetles of the black lady-beetle, *Rhizobius ventralis* Erichson, fed upon this scale insect when in captivity, and in all probability feed upon it when free, as it is usually found abundant upon scale-infested trees. The common black-spotted red lady-beetle, *Hippodamia convergens* Guérin, and its variety, *ambigua* LeConte, have been found rather plentiful upon infested trees and probably prey upon this scale insect, yet none have been observed actually feeding upon it.

The green lacewing *Chrysopa californica* Coquillett has also been reared upon the European elm scale and is found to some extent upon infested elms. No other insect enemies of this pest have been observed.

CONTROL EXPERIMENTS.

TABLE 1.—*Experiments performed upon the European elm scale.*

No.	Date.	Spray material.	Dilution.	Trees.	Scales killed.	Remarks.
					Per cent.	
1	Apr. 15, 1918	Water	100 to 160 pounds pressure.	191	85	Used fire engine and hose, large trees.
2	Apr. 19, 1918	do	50 pounds pressure.	2	95	Used garden hose and nozzle, small trees.
3	Apr. 26, 1918	do	do	1	80	Used garden hose, extension rod, and 12-foot platform, medium-sized tree.
4	May 14, 1919	do	do	2	97	Used garden hose, small tree.
5	Dec. 3, 1918	Distillate emulsion	1 to 5	3	60	Hibernating larvæ.
6	Mar. 5, 1919	Crude-oil emulsion	do	3	60	Do.
7	do	Distillate emulsion	1 to 4	8	60	Do.
8	do	Kerosene emulsion	1 to 4.5	3	25	Do.
9	do	Distillate emulsion	1 to 4	1	65	Do.
10	Apr. 12, 1919	do	do	3	60	Trees in leaf, slight burning.
11	Jan. 19, 1920	Crude-oil emulsion	1 to 5	4	60	Hibernating larvæ.
12	do	Distillate emulsion	1 to 4	3	20	Do.
13	do	do	1 to 3	3	20	Do.
14	Apr. 12, 1919	Fish-oil soap	1 pound to 7 gallons.	3	5	Trees in leaf, no burning, young females.
15	do	Lime-sulphur	1 to 9	3	20	Do.
16	Dec. 3, 1918	Miscible oil, 33°	1 to 12	5	10	Hibernating larvæ.
17	Mar. 5, 1919	Miscible oil, 28°	1 to 7	3	99	Do.
18	Jan. 19, 1920	do	do	4	98	Do.
19	do	do	1 to 9	2	100	Do.
20	Mar. 4, 1920	Miscible oil, 33°	do	4	30	Do.
21	do	do	1 to 12	3	20	Do.
22	do	Miscible oil, 28°	1 to 9	3	97	Do.
23	do	do	1 to 12	4	99	Do.
24	Apr. 19, 1920	do	1 to 15	2	40	Young females.
25	do	do	do	2	95	Do.
26	do	do	1 to 12	1	98	Do.

In experiment No. 1 the trees were large, in No. 3 the tree was medium-sized, and in all the others the trees were small and could be sprayed from the ground with an ordinary bucket pump. This was the apparatus used, except in the first four experiments, where water was applied. All but one of the experiments were performed at San Jose, Calif., upon the elms growing on the normal school grounds.

WASHING EXPERIMENTS.

Washing the scale from the elm trees with a solid stream of water was experimented with, since fairly good results had been obtained in this manner by Prof. S. B. Doten, of Nevada (*3, 4*). In fact, his results seemed more satisfactory than spraying with a lime-sulphur solution or kerosene emulsion.

In preliminary experiments, it was found that the best nozzle that could be obtained for the usual pressure of 50 pounds to the square inch on the garden hose was one with a 3/16-inch outlet and a long taper.

On small trees this equipment was used to good advantage to wash the mature scale insects from their resting places. (Fig. 4.) All limbs were within easy reach and the trees so small that a thorough washing was possible. The results obtained were highly satisfactory and the trees remained clean until reinfested in the fall.

On medium-sized trees the same apparatus was used, with the addition of a 12-foot platform and a 7 or 8 foot extension rod. This proved to be too tedious and was only moderately successful even when done carefully.

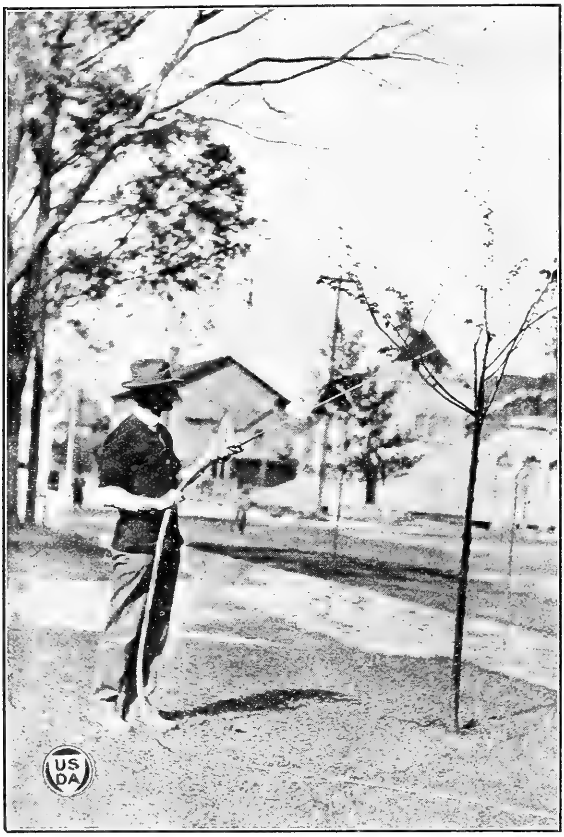


FIG. 4.—Washing young elm tree with garden hose and nozzle to remove the European elm scale.

On large trees it was necessary to have a greater pressure and volume of water in order to obtain satisfactory results. This was obtained by using a fire engine, supplemented with 1,000 feet of $2\frac{1}{2}$-inch hose, a short tapering nozzle with a circular $\frac{7}{8}$-inch opening, and a stand to facilitate holding the nozzle. (Fig. 5.)

It was possible to use a pressure of 160 pounds without doing any damage to the foliage already out. It proved beneficial, in fact, by removing all dead twigs and branches and incidentally giving the trees and lawns a good irrigating.

The crew consisted of one foreman, one engineer, and three hosemen, this number being necessary in order to move the heavy hose without delay.

With this apparatus and crew 191 large trees were satisfactorily washed in six days at an approximate cost of $1.20 per tree. During all the following summer the trees remained very clean, one or two showing evidence of the presence of a few scale insects by a slight drip. The writer estimated that about 85 per cent of the scales had been removed. One year later, however, the trees were again infested rather badly, owing partly to the remaining 15 per cent and to a reinfestation from the surrounding well-infested trees.

The results of these washing experiments have been previously reported in considerable detail (*9*).

SPRAYING EXPERIMENTS.

Sprays consisting of distillate emulsion, kerosene emulsion, or crude-oil emulsion at strengths varying from 3 to 5 parts water to 1 part emulsion proved entirely unsatisfactory for the control of the European elm scale, only 20 to 60 per cent of them being killed. A solution of 1 pound of fish-oil soap and 7 gallons of water was used upon some molting females but was completely unsuccessful. Although other experimenters have reported fair results from the use of lime-sulphur, the writer's results with it were unsatisfactory, practically none of the insects being killed. This material can not be used in shade-tree work to any great extent because the sulphur in it combines with the paint on buildings and turns it black.

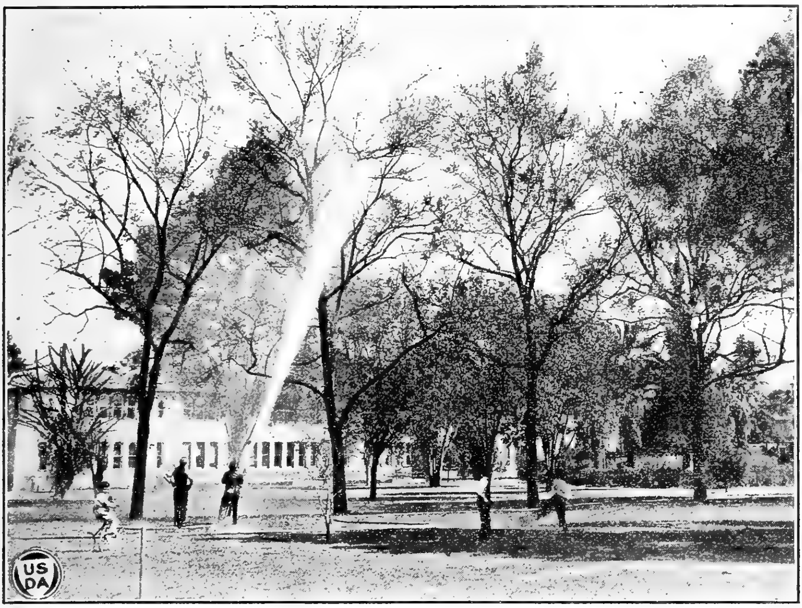


FIG. 5.—Washing large elm trees with water from fire engine to remove the European elm scale.

The best results were obtained from miscible-oil sprays. Those containing 28° Baumé oil were found to be very satisfactory, whereas those containing 33° gave very poor results. The former were efficient at the proportions of 1 part oil to 9 and 12 parts water, and certain brands of them at the greater dilution of 1 to 15 parts water. Miscible oil 28°, 1 part to 12 parts water, is the material to be recommended.

RECOMMENDATIONS FOR CONTROL.

Either of two materials is recommended for the control of this insect, a solid stream of water or a miscible oil spray. The garden hose and nozzle may be used to good advantage where a few small

trees need to be rid of this pest. The ordinary pressure of water from the hydrant will remove the insects at a distance of 10 or 12 feet. Each limb and twig must be hit with a solid stream of water from at least two directions. The use of a fire engine and equipment is quite satisfactory on trees over 20 feet high. It probably does not produce as good results as when a high-capacity spray outfit is used, but when the former is available and the latter is not, it is recommended for large trees. It is cheaper than spraying and can not damage the elms.

All washing should be done in the spring just before the leaves appear on the trees, usually about the middle of April. The fruits

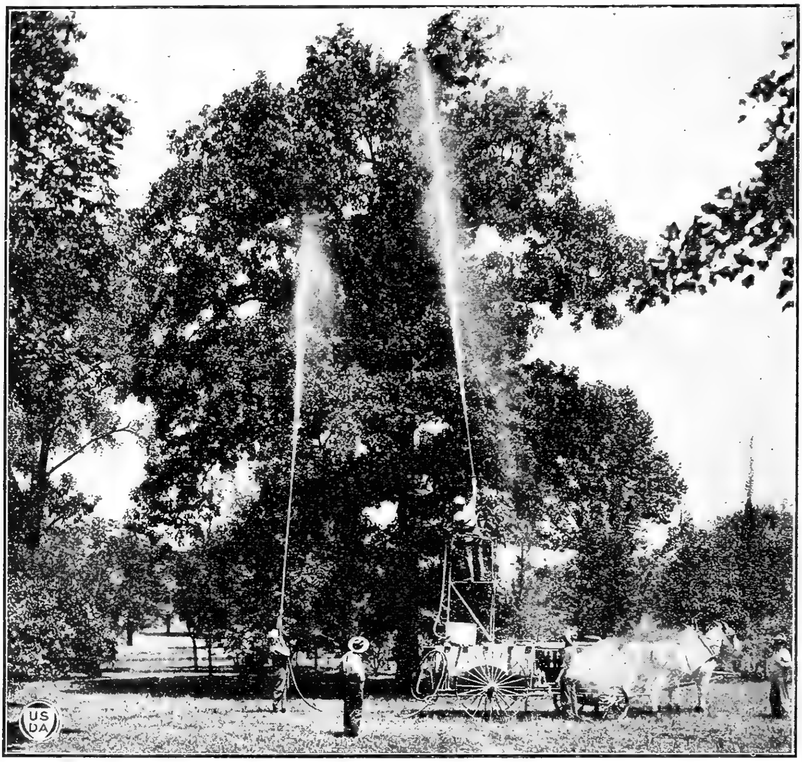


Fig. 6.—Spraying large elms with high-power outfit to remove the European elm scale.

or small winged seeds begin falling from the trees about a week before the leaves appear, thus providing a warning that the washing should be done soon. At this time the female scales are large, being full of eggs, and are easily washed from the trees. This washing could be done at any time until egg laying begins, five or six weeks later, were it not for the presence of the foliage, which impedes the force of the stream. Thus to insure success in washing there must be a solid, forceful stream of water, and it must be used at the proper time.

A more satisfactory method of control is the use of miscible oil containing 23° to 28° Baumé oil, which can be obtained from dealers under various trade names. This should be used in the following proportions:

Miscible oil (23° to 28° Baumé)	1 gallon or 16 gallons.
Water	12 gallons or 184 gallons.

It is mixed by first pouring the requisite amount of oil into the spray bucket, barrel, or tank to be used and then adding a small amount of water. With considerable agitation this will become light-colored and of a creamy consistency, whereupon more water may be added, and finally all the water, in the meantime agitating thoroughly. This may then be applied with any sort of spray outfit, providing the apparatus has power enough to send a spray to the tree tops.

The bucket or barrel pump will do very well for small trees, the ordinary orchard power outfit for trees up to 40 feet in height, and a high-power apparatus for trees above this height. (Fig. 6.) A pump registering a pressure of at least 300 pounds with a capacity of 12 to 15 gallons or more per minute is necessary to reach trees 60 to 90 feet high, which is often the height of mature elms. A spray gun or solid-stream Worthley nozzle is necessary to force the spray to the tops of the trees from the ground. The use of a smaller outfit and ladders is not to be recommended, on account of extra cost and unsatisfactory results.

Large trees require from 30 to 50 gallons of mixture, costing from 3 to 4 cents per diluted gallon for the material and 1½ to 2½ cents per gallon to apply it.

Every branch and twig should be covered, but too much spray should not be allowed to settle about the base of the tree, as it might injure the roots. No damage to elm trees or lawns has been noted, however.

The spraying should be done in the winter up to the time the buds begin to open in the spring. Probably a weaker spray could be used on the young forms in the late summer but this would be about as expensive, for nearly twice the amount of material would be required to cover each tree on account of the foliage, and it would be much less satisfactory since all parts, particularly the underside of the leaves, which are the most heavily infested, could not be thoroughly covered.

If properly done, spraying should not be necessary every year, except upon young trees, which seem to become reinfested easily when near unsprayed large trees. Extermination, of course, is not to be hoped for, but it is possible to kill a sufficiently high percentage of the insects to prevent their appearance in large numbers the following season.

SUMMARY.

The European elm scale was introduced into this country about 1884 from Europe and was first found at Rye, N. Y. From there it has spread until it is now located in 27 States and the District of Columbia. Although more widespread in the East, the injury to

trees is not as great as in the West. This insect infests only elms, doing damage particularly to young trees, but killing twigs and branches of the older ones. It causes the leaves to turn yellow and drop early, besides making foliage and ground black and sticky from its secretion of honeydew.

The first-stage larva is a small, yellowish, oval object about 0.5 millimeters long. The second-stage larva is over twice as long as the first, and is reddish brown, but appearing gray from the waxy coat on its back. The adult female is large and oval, about 2 millimeters long, and of a dull red-brown or green-brown color, surrounded by a white cottony fringe of wax.

The second-stage larvæ hibernate in the bark crevices and about the winter buds. In early spring the male larvæ form cocoons and transform in them to adults. By this time the female larvæ have molted and seek a sheltered place on the underside of the limbs and branches. After mating they form a waxy fringe about their bodies and in late spring or early summer begin to deposit their eggs. This they continue to do throughout the summer, and upon completing oviposition they shrivel and die. The larvæ hatch very soon from these eggs and crawl to the midribs of the leaves or in some case remain in the bark crevices. All molt to the second stage. Those on the leaves move in the fall to more premanent winter quarters on the twigs and about the buds, where they remain until activity begins again in the early spring.

Several lady-beetles feed upon the European elm scale but are not plentiful enough to be considered as important enemies. A number of sprays have been experimented with, but only washing in the spring with a solid stream of water and spraying in the winter with a solution of 23° to 28° Baumé miscible oil, 1 part oil to 12 parts water, have proved effective in the control of this pest.

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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1225

Washington, D. C. ▼ April 30, 1924

THE CAMPHOR THRIPS.[1]

By W. W. Yothers, *Entomologist*, and Arthur C. Mason, *Assistant Entomologist, Fruit Insect Investigations*,[2] *Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

Many years ago camphor trees, *Cinnamomum camphora* (L.) Nees & Eberm., were introduced into Florida for ornamental uses. The beauty and grace of the tree made it very popular for the beautification of grounds, roadways, and borders of groves. The ease with which this tree was propagated and the luxuriousness of its growth (fig. 1) led to the belief that it could be grown in large acreages to obtain a commercial supply of camphor.

The first attempt to produce camphor gum under commercial conditions was made at Satsuma, Fla., in 1903. The total investment on this plantation amounted to nearly one million dollars and during the period of the existence of the plantation (1903–1921), 1,800 acres were set to camphor trees. Another plantation, consisting of 2,200 acres of camphor trees, was located at Waller, Fla., midway between Stark and Green Cove Springs, and represented an investment of over a million dollars. It was thought that by using machinery on an extensive scale camphor gum could be produced as economically here as in the Oriental countries, where the cost of labor is low. Practically all of the work of planting the trees, cultivating, harvesting the branches for distillation, and producing the camphor gum itself was done by mechanical means.

[1] *Cryptothrips floridensis* Watson; family Phloeothripidae, order Thysanoptera.

[2] The present investigations were begun by C. A. Weigel, of the Bureau of Entomology, assisted by C. A. Bennett, who conducted a large part of the field work during the first year. Practically all the biological work was done at Orlando, Fla., by the junior writer, together with observations made at the camphor farm at Satsuma, Fla. The control work was done mostly on the camphor plantation at Satsuma, and in addition pruning and spraying experiments were carried on at Orlando. Similar life-history work was carried on at Gainesville, Fla., by Prof. J. R. Watson, to whom credit is given for certain notes and valuable assistance. The writers desire also to express their appreciation to C. W. Loveland, manager of the camphor plantation at Satsuma throughout the period of the investigations, who extended to them many courtesies as well as material aid during the progress of the work.

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Many obstacles to the production of camphor in commercial quantities at a reasonable price were soon encountered, the most serious of which was the injurious effect on the trees of the usual method of pruning or harvesting the branches. The practice was to cut the

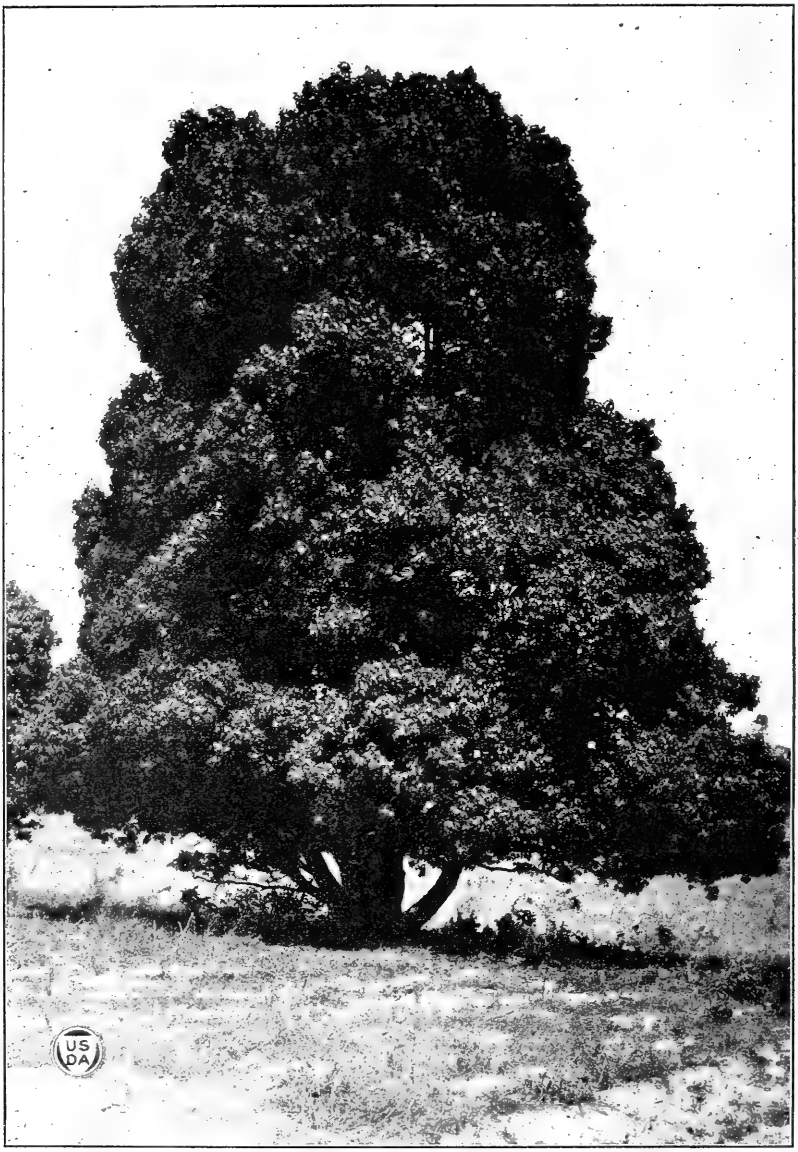


FIG. 1.—Camphor tree showing characteristic habit of growth.

branches from the top and sides of the tree each year, the cuts being made without regard to the nodes. In many instances this left from 1 to 12 inches of the branch extending beyond the node. Since camphor trees, except in rare cases, do not put out new branches

between the nodes, the cut end invariably died back to the node. In these dead ends injurious fungi and borers developed and often their effect extended beyond the node.

Plants thus treated are always stimulated to new growth. When this occurred in late fall or winter the trees were not able to resist low temperatures which an unpruned tree could withstand without the slightest damage. The combined effect of the method of pruning and the injury from cold was a great set-back to the growth of the trees, resulting in the dying back of many large limbs and in some cases the death of the trees.

The camphor thrips was a third obstacle to camphor production. This pest appeared in great numbers on the cut ends and on the new shoots that follow pruning. This new growth appeared to furnish an unlimited food supply for the thrips, which multiplied without any apparent restriction. The effects of the thrips on trees thus pruned was very marked. Plate IV, B, shows a tree attacked by the thrips, following the usual pruning, resulting in the death of many of the limbs.

To discover means of controlling this pest, preliminary investigational work was carried on by Prof. J. R. Watson (*3, 6*),[3] Florida Agricultural Experiment Station, Gainesville, Fla. This work showed that the insect was spread over the entire plantation at Satsuma, Fla., and also indicated that it would be a difficult and expensive pest to control by any artificial means. The seriousness of the situation led Congress to appropriate funds with which to work out some economical method for the commercial control of this pest. The work began as a special project of the Bureau of Entomology, with Professor Watson cooperating. After about a year the project was placed under the Tropical and Subtropical Fruit Insect Investigations, where it was continued over a period of two more years.

HISTORY AND DISTRIBUTION.

The camphor thrips was first discovered at Satsuma, Fla., in November, 1912, by William O. Richtman (*8*), who found the pest spread over the entire plantation and was very much alarmed by its apparent ravages. It has since been found in many parts of Florida, including Orlando, Clearwater, Oneco, Sebring, Daytona, Fort Pierce, and Glen St. Mary, and no doubt may be found in all locations about these places. In fact its range is now known to cover all of Florida except the extreme southern part. Search has been made for it in Dade County but without success, though very few camphor trees are grown in that part of the State. The thrips also occurs on camphor trees in Alabama, Mississippi, and Louisiana, and probably in Georgia, since it has been found close to the Florida-Georgia State line. In all probability the camphor thrips will be found throughout the range of the camphor trees. Camphor trees grown as ornamentals will probably not suffer to any serious extent from the ravages of this pest, but it is quite certain that in hedges which are pruned back at frequent intervals camphor will be severely damaged by the thrips, a fact which may necessitate the abandonment of camphor for ornamental hedges.

[3] Figures in parenthesis (italics) refer to "Literature cited," p.29.

ORIGIN.

The original theory of Watson (*5*) regarding the origin of the camphor thrips was that it had been introduced into Florida on nursery stock from the Orient and was therefore peculiar to the camphor. Since camphor trees are not indigenous to the United States, this seemed to be a reasonable explanation. Later investigations, however, tended to show that the thrips might be a native insect and had taken to the camphors because of their close relationship to its natural hosts. Watson (*11*) states that the bay trees of the genus Persea (Tamala) are the natural hosts of the camphor thrips. He found a thrips on the bays which was very similar to *Cryptothrips floridensis* and concluded therefore that these were the camphor thrips in their native habitat. Careful and extended investigations by the junior author, however, have shown this bay thrips to be a new, although closely related species. It was therefore described (*12*) as *Cryptothrips laureli* n. sp. Because of the close similarity of the adults in the two species, as well as the relationship of their hosts, it was reasonable to believe from a superficial examination that they might be the same species. There are, however, some distinguishing structural characters which were revealed after a study of the immature forms and habits had shown them to be distinct from the camphor thrips.

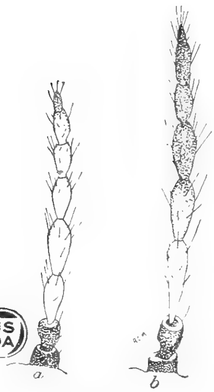


FIG. 2.—Structural characters of antennæ of the camphor thrips and the bay thrips: *a*, Antenna of camphor thrips: *b*, antenna of bay thrips. Enlarged.

COMPARISON OF BAY THRIPS AND CAMPHOR THRIPS.

The camphor thrips is fully described in later pages. The bay thrips differs from it in the following structural characters: Larger size; antennæ longer and darker colored and with the third segment especially larger and more slender in shape (fig. 2); stronger spines on the head and thorax and a much smaller number of doubled hairs on the fringe of the fore wings. The eggs are larger also than the eggs of the camphor thrips, are light straw-yellow instead of black, becoming red during the development of the embryo, and are covered with irregular scale-like patches rather than the regular hexagonal pattern (fig. 5) of the camphor thrips. The distinguishing character of the larva and the pupa is the bright and conspicuous carmine red color compared with the dull orange red of the camphor thrips. The time required for development is also longer in all stages. In the adult stage different feeding habits are found, and usually sexual reproduction instead of parthenogenesis.

The food preferences of these two thrips are also different. Although the bay thrips can be made to live on camphor, no instances have ever been found in which it had taken to the camphors naturally. Its natural hosts include only the four species of Persea which are native of Florida (*4*). On the other hand, the camphor thrips will live on camphor only and could not be made to live on bay, as will be shown in detail later. Several generations of the bay thrips

reared on camphor in cages did not change their appearance or habits in any way. The conclusion may therefore be drawn that the camphor thrips has originated from another source. Since it does not occur on any of the native trees of the family Lauraceae, it, in all probablilty, must be an introduced species. No evidence, however, has been obtained of its presence in any of the countries where camphor trees are indigenous. The specimens received by Watson from Ceylon and reported (5) as *Cryptothrips floridensis* have since been determined as a different species.

NATURE AND EXTENT OF INJURY.

The injury from the camphor thrips seems to be confined almost entirely to pruned trees or trees previously injured from other causes.

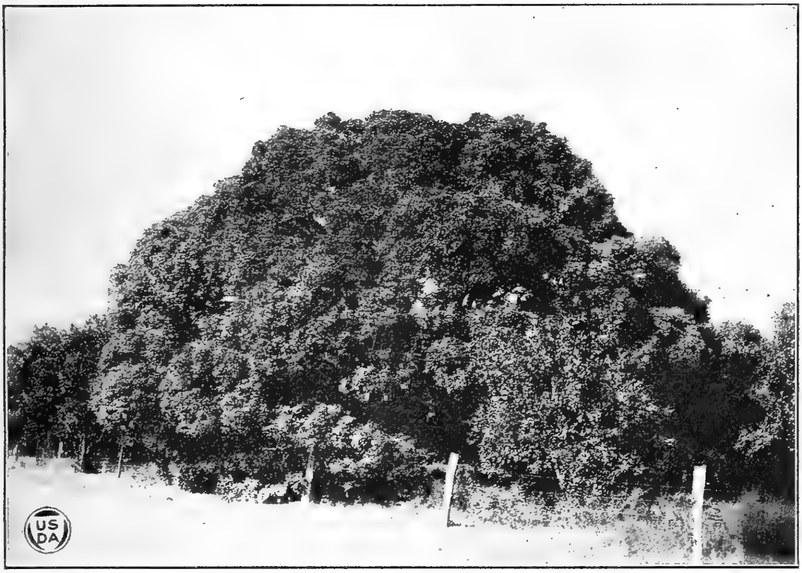


FIG. 3.—A 40-year-old camphor tree, showing magnificent size which these trees can attain when uninjured by pruning or thrips.

When grown as an ornamental or shade tree and not cut back, the camphor tree is very luxuriant and often attains great size. While the thrips can often be found on such trees, they have never been seen in large numbers or been known to do any appreciable damage to such trees. Many beautiful specimens of the camphor tree can be found over the State in regions where thrips occur and are even abundant on pruned trees. The tree illustrated in Figure 1 is growing on the camphor farm at Satsuma near the fields in which the thrips have been most injurious. Figure 3 illustrates one of the largest camphor trees in the State. This tree, planted in 1880, now has a circumference of 16 feet 3 inches, with an average spread of 60 feet and a height also of 60 feet. Throughout its growth it has been comparatively free from any pests which have unduly interfered with its development. Camphor trees have also proved valuable as windbreaks for citrus groves and when planted as hedges and allowed

to grow unhindered they attain great size and become remarkably beautiful (fig. 4).

When grown for ornamental hedges along streets or in dooryards, however, where it is necessary to keep the trees pruned back regularly, they suffer considerable damage from the thrips. They suffer also when the trees are cut back to procure material for distillation. The insects collect in great numbers around the cut ends and feed upon the plant tissues. In addition they destroy the buds (Pl. II) and new growth when put forth by the trees, and even work in the limbs (Pl. III), causing the bark to crack (Pl. IV, A) and later the limbs to become deformed (Pl. V). Their chief damage is probably to the buds, and when present in any great number they prevent the trees from putting forth very much new growth, without which

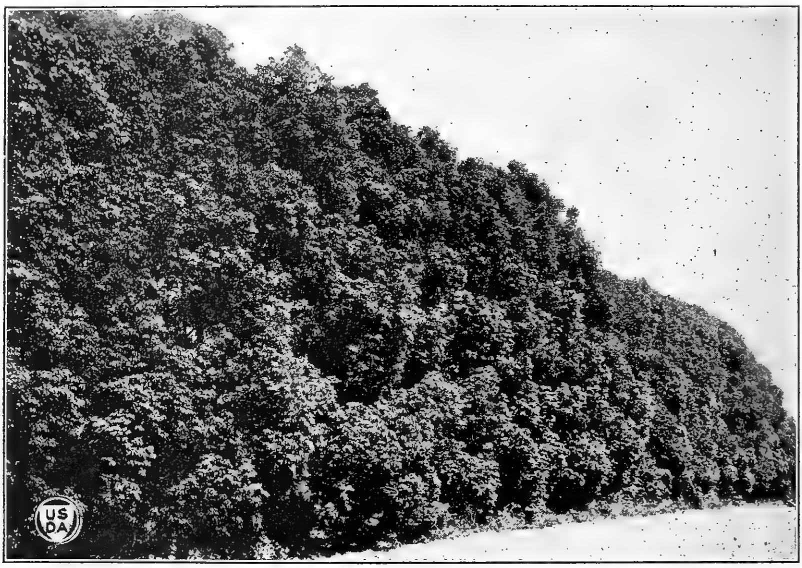


FIG. 4.—Row of camphor trees planted as a windbreak for a citrus grove. When uninjured the trees make a beautiful hedge and are not seriously attacked by the camphor thrips.

camphor production is cut off. As will be shown later, the usual pruning practices had to be changed. Instead of pruning the trees promiscuously and cutting the limbs back to stubs it was found necessary to cut the trees off at the level of the ground.

DESCRIPTION.

ADULT.

The original description of the adult (Pl. I, A) was by Prof. J. R. Watson (*1*), as follows:

Cryptothrips floridensis, new species.

Measurements: Head, length 0.25 mm., width 0.20 mm.; prothorax, length 0.17 mm., width 0.34 mm.; mesothorax, width 0.40 mm.; abdomen, width 0.44 mm.; total length of insect, exclusive of antennae, 1.89 mm.; tube, length 0.14 mm., width at base 0.075 mm.; antennae, 1, 36 μ; 2, 51.7 μ; 3, 77.6 μ; 4, 78 μ; 5, 65 μ; 6, 63 μ; 7, 54.5 μ; 8, 40 μ; total 0.42 mm.

General color, black, no purple pigment; tarsi dark brown and antennae yellow.

Head, cylindrical, one and one-fourth times as long as wide; sides almost straight and parallel.

Eyes somewhat triangular, 9 × 6 μ, reddish brown, not pilose, about 250 facets.

Ocelli present, concolorous with the eyes to which the posterior ones are closely applied.

Mouth-cone, rather bluntly rounding, reaching three-fourths of the way across the pronotum.

Antennae with eight segments, one and two-thirds times as long as the head; segments one and two black, concolorous with the head, segments three to six clear yellow, eighth and tip of seventh yellowish-brown.

Prothorax short, a little shorter than the width of the head, triangular, narrow in front, well-developed spines on posterior angles and two on the anterior part of each lateral margin.

Mesothorax wider than the prothorax and very short, sides almost straight.

Pterothorax a little narrower than the abdomen, sides almost straight.

Legs long, concolorous with the body except the brown tarsi.

Wings: Fore-wings reaching almost to the end of the abdomen, fringed with hairs which are nearly as long as the width of the abdomen, doubled for from 15 to 19 hairs, nerve weak and short, constriction rather slight.

Abdomen usually long and slender, usually widest at the second or third segment and tapering gradually to the seventh from which it rounds off more abruptly. A pair of bluntly-tipped hairs along the margin of each segment, becoming longer and arising from nearer the posterior angle on the posterior segments. The tube is 0.14 mm. long and about 0.075 mm. wide at the base. The end bears a circle of stiff hairs, eight of which are about two-thirds as long as the tube, six are shorter and weaker.

Males are similar but smaller.

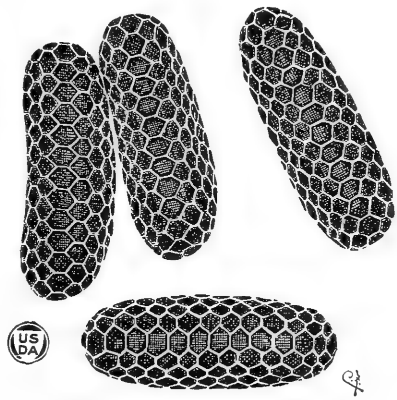


FIG. 5.—Eggs of the camphor thrips. Greatly enlarged.

EGG.

The following description of the egg and those of the larval stages are original.

The eggs (Pl. I, B; fig. 5) average about 0.37 by 0.15 mm. in size and are dull black throughout the life of the egg. The entire surface is reticulated, being covered with a network of waxy material arranged regularly and giving the shell the appearance of being divided into hexagonal plates.

FIRST-STAGE LARVA.

When first hatched, the young larvæ (Pl. I, C) are a light straw color and fusiform, the legs and antennæ being disproportionately large and giving the insects an ungainly appearance. The average length is nearly 1 mm. and the width of mesothorax about 0.17 mm. The eyes are dark brown and the head, antennæ, legs, and the last two abdominal segments are light brown. The thorax contains two light-brown spots so large as almost to cover it and make it appear brown with a yellow stripe through the center. On the dorsal surface of each abdominal segment is a row of six brown dots from which arise short colorless hairs. These dots are so arranged as to form six longitudinal rows along the entire length of the abdomen.

SECOND-STAGE LARVA.

Average measurements of the second-stage larvæ (Pl. I, D) when full grown are: Length 2.29 mm.; width of mesothorax 0.547 mm. General color orange red. The body is a light yellow to whitish color, but appears orange red owing to the presence of numerous very small, irregularly shaped blotches of orange-red pigment underneath the epidermis. The antennæ, legs, and last two abdominal segments are light brown. The head also is light brown, with a narrow yellow streak through the center. The eyes are dark brown. The thorax is yellowish, with two large brown spots divided by a narrow yellow stripe through the center. A number of moderately conspicuous hairs occur along the abdominal segments.

PREPUPA.

Average measurements of the prepupa (Pl. I, E) are: Length 2.27 mm., width of mesothorax 0.537 mm. Somewhat smaller than the preceding stage and lighter in color. The blotches of pigment now appear larger and not so numerous throughout the body, which is whitish or almost transparent. The head and thorax are white, with little coloring except for the eyes, which are larger and reddish brown. The last abdominal segment is light brown. The legs are colorless and the antennæ, which are short, heavy, and folded back along the head, are also colorless. The wing pads show as short colorless sacs. Numerous long whitish hairs appear on the antennæ and abdomen.

PUPA.

Average measurements of the pupa are: Length 1.98 mm., width of mesothorax 0.417 mm. The pupa (Pl. I, F) is smaller than the prepupa, but similar in color, except for the presence of a little more pigment, particularly in the head and thorax. The antennæ are now longer but folded back along the head. The wing pads are longer, reaching about the third abdominal segment. Numerous long white or colorless hairs are on the legs, antennæ, and abdomen.

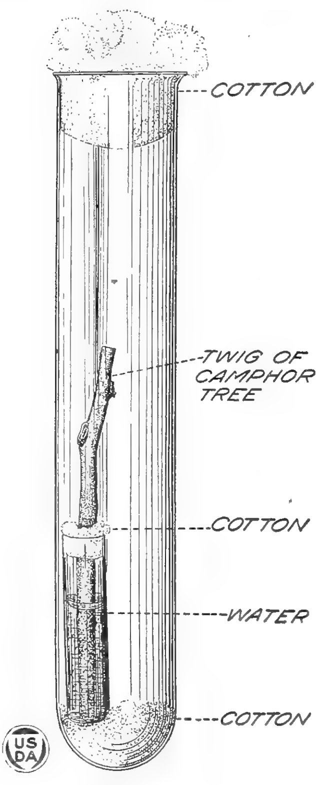


FIG. 6.—Test tube used as a breeding cage for the camphor thrips.

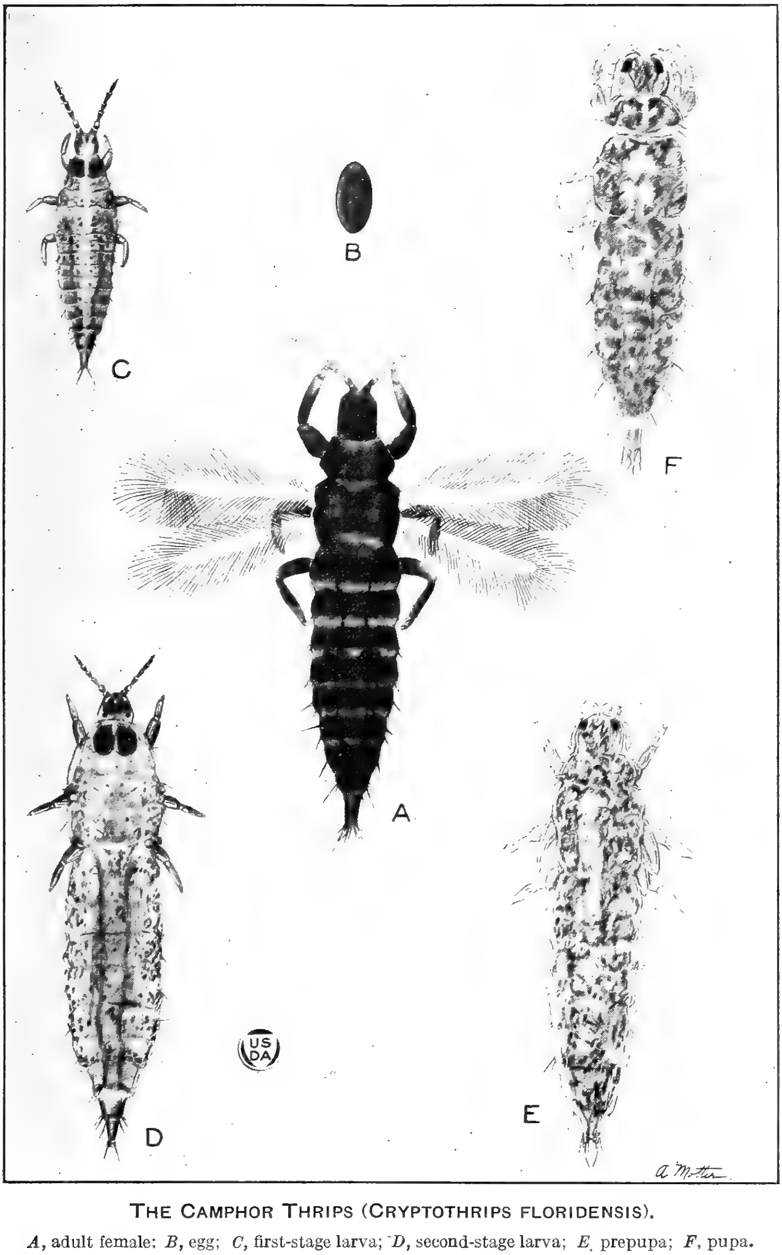
MALES.

In the larval and pupal stages the males are somewhat smaller than the females and have a distinct purple color, but otherwise are similar in structure and appearance. They occur very rarely in nature.

LIFE HISTORY AND HABITS.

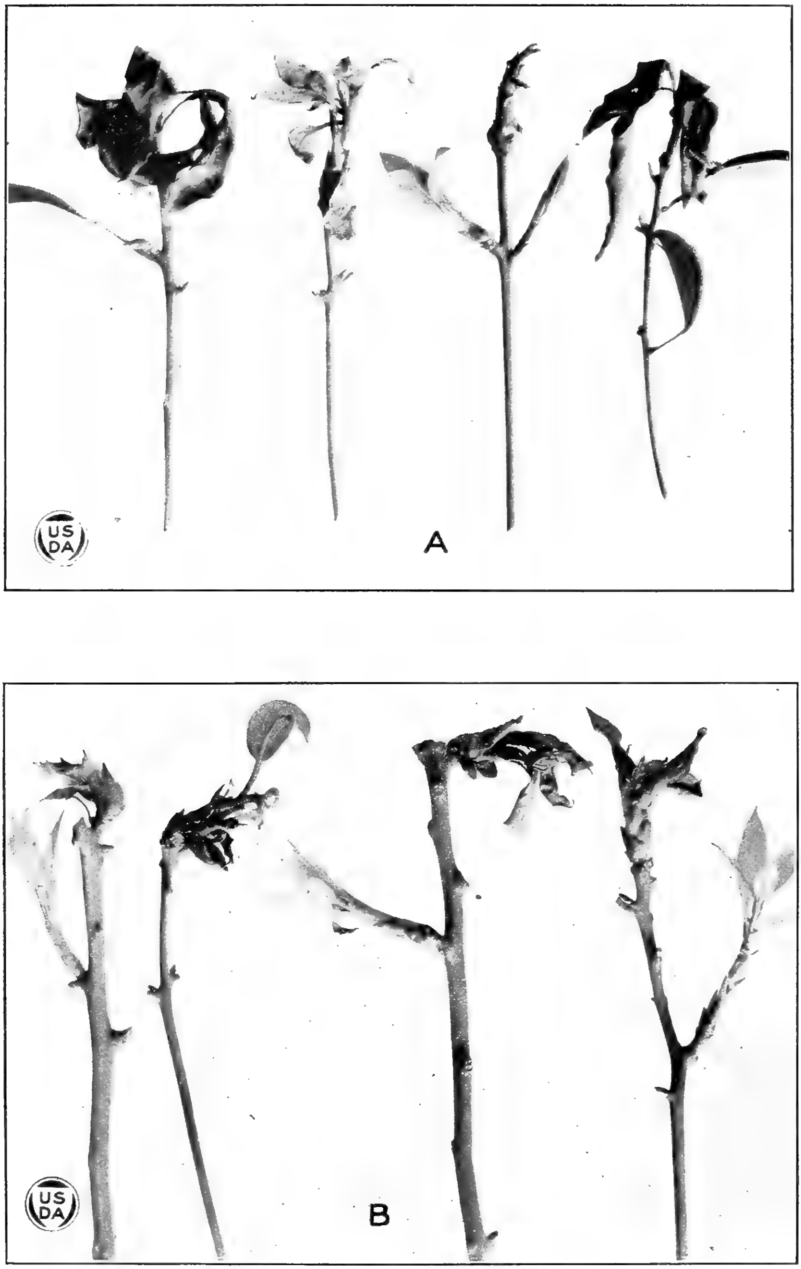
METHODS OF REARING.

The life history of the camphor thrips was worked out in the laboratory under conditions as nearly natural as possible, with daily observations on the insects infesting growing trees. The work was carried on in summer and also during the cooler weather of winter. Test tubes were employed as breeding cages and the thrips confined on small pieces of camphor twig. (Fig. 6.) The twigs were cut in lengths of about 3 inches and placed in water in small shell vials, the mouth of the vial being filled with cotton which surrounded the twig and held it in place. This vial was then dropped into a test tube and the test tube stoppered with cotton. The immature stages of the thrips were usually held on the camphor twigs by the cotton, but should one succeed in crawling over the cotton it was confined inside of the test tube and could be replaced on the twig. The adults would fly across on to the test tube, but would return to the twigs to feed and oviposit. In all experiments fresh food was given the thrips every few days and they were kept until they died a natural death. Owing to the activity of the thrips and their small size, some of them were lost or injured in transferring to new cages or new food.



THE CAMPHOR THRIPS (CRYPTOTHRIPS FLORIDENSIS).

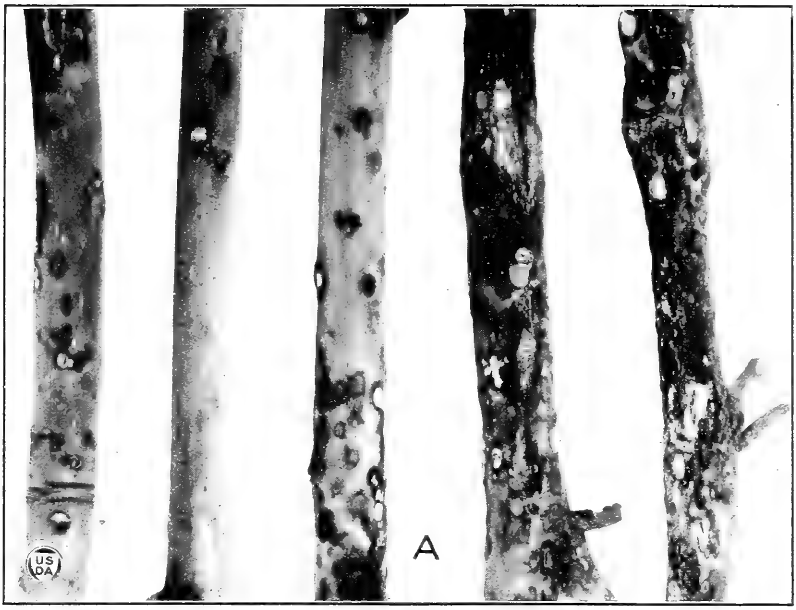
A, adult female; *B*, egg; *C*, first-stage larva; *D*, second-stage larva; *E*, prepupa; *F*, pupa.

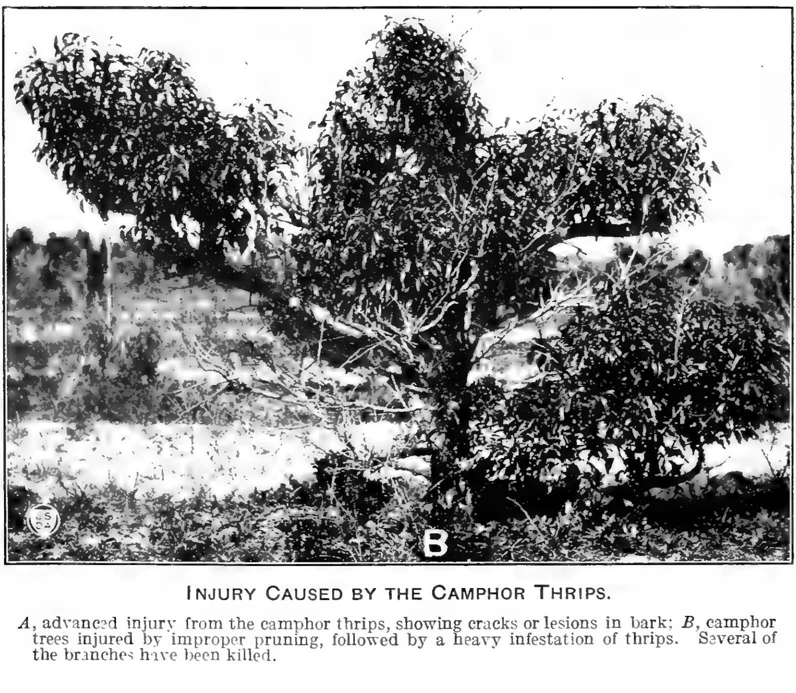


INJURY TO CAMPHOR BUDS CAUSED BY CAMPHOR THRIPS.

The terminal buds are badly deformed or entirely killed.

SMALL LIMBS OF CAMPHOR TREES SHOWING CHARACTERISTIC SPOTS CAUSED BY PUNCTURES OF THE CAMPHOR THRIPS.





INJURY CAUSED BY THE CAMPHOR THRIPS.

A, advanced injury from the camphor thrips, showing cracks or lesions in bark; *B*, camphor trees injured by improper pruning, followed by a heavy infestation of thrips. Several of the branches have been killed.

Hence some difficulty was encountered in keeping the thrips for long periods, and many cultures were started in order to complete the desired number.

DURATION OF LIFE CYCLE.

As observed by the writers, the life cycle of the camphor thrips varied considerably according to the season of the year. In August, 1921, 375 eggs required an average of 6 days in which to hatch, and the combined larval and pupal stages for 57 individuals averaged 12.65 days, giving an average of 18.65 days from egg to adult. The average life of 20 adults during the summer months was 98 days, and they laid an average of 463.7 eggs.

During this period (August, 1921) the maximum temperature at the laboratory in Orlando, Fla., ranged from 88° to 100° F., with a mean maximum of 94° and a mean minimum of 71.2°. The total precipitation was 4.13 inches.

The winter-season breeding work was carried on during November and December, 1921, and January, 1922. During this period 97 eggs required an average of 13.6 days in which to hatch and the combined larval and pupal stages for 40 individuals averaged 24.7 days, making a total of 38.3 days from egg to adult. The average life of 20 adults was 82.8 days, and the average number of eggs laid was 307. The temperatures during this period were as follows: In November, 1921, the maximum temperatures ranged from 71° to 86°, with a mean of 79.5°, and the mean minimum temperature was 53.9°. The total precipitation was 3.62 inches. For December the maximum temperatures ranged from 65° to 80°, with a mean of 74.3°, while the mean minimum was 48.6° and the total precipitation was 2.23 inches. For January, 1922, the maximum temperatures ranged from 61° to 84°, with a mean of 77.3°. The mean minimum was 50.1° and the total precipitation was 0.52 inch.

Allowing for the preoviposition period, which averaged 3.2 days in summer and 7.4 days in winter, the average period of development in summer from egg to egg would be 21.85 days and in winter 45.7 days. Judging from these figures, the maximum number of generations of the camphor thrips per year would be about 12.

THE EGG.

INCUBATION PERIOD.

The time required for development of the egg varies considerably even at the same time of the year. During the warmer weather this period ranges from 5 to 9 days, with an average of 6 days, while in the cooler weather of winter it ranges from 10 to 16 days, with an average of 13.6 days. Thus the egg requires more than twice as long to develop during the cooler part of the year. A variation of 2 or 3 days was also observed in the development of eggs laid on the same day by the same female. The percentage of eggs hatching seems to be very high, averaging 98.2 per cent in summer and 86 per cent in winter. The detailed records on incubation of the egg are given in Table 1.

TABLE 1.—*Incubation period of camphor thrips eggs.*

IN SUMMER.

Record No.	Date eggs were deposited.	Number of eggs deposited.	Number of eggs developing in specified number of days.					Number of eggs failing to hatch.
			5 days.	6 days	7 days.	8 days.	9 days.	
	1921.							
1	Aug. 4	3		2	1			0
2	Aug. 5	10		6	2		1	1
3	..do....	11		9	1			1
4	Aug. 6	3		3				
5	..do....	6	2	3				1
6	Aug. 7	17	3	8	6			
7	..do....	8	1	7				
8	Aug. 8	21	2	10	6	3		
9	..do....	3		3				
10	Aug. 9	20	1	10	9			
11	..do....	2		1	1			
12	Aug. 10	17	4	11	2			
13	..do....	23	2	18	3			
14	Aug. 11	6	2	3	1			
15	..do....	13	3	10				
16	Aug. 12	18	3	13	2			
17	Aug. 13	20	5	10	5			
18	Aug. 14	16	5	9	2			
19	Aug. 15	10	6	4				
20	Aug. 16	32	15	15	2			
21	Aug. 17	26	1	18	7			
22	Aug. 18	31	7	22	2			
23	Aug. 19	18	4	9	5			
24	Aug. 20	28	9	11	7	1		
25	Aug. 21	20	3	10	3			4
Total		382	78	225	67	4	1	7

IN WINTER.

Record No.	Date eggs were deposited.	Number of eggs deposited.	Number of eggs developing in specified number of days.							Number of eggs failing to hatch.
			10 days.	11 days.	12 days.	13 days.	14 days.	15 days.	16 days.	
	1920.									
1	Nov. 15	9				1	1	2	2	3
2	Nov. 12	4			1	1		1		1
3	Nov. 17	2					1	1		0
4	Nov. 19	3					1	2		0
5	Nov. 20	2					1			1
6	Nov. 23	8					4	2		2
7	..do....	4					1			3
8	Nov. 29	6			2		3	1		0
9	Dec. 1	4				1	2	1		0
10	Dec. 3	3				1	1	1		0
11	Dec. 6	3						2	1	0
12	Dec. 9	3					1	2		0
13	Dec. 11	2					1			1
14	Dec. 18	2						1		1
15	Dec. 20	4				1	1	1		1
16	Dec. 21	2				1	1			0
17	Dec. 22	2				2				0
18	..do....	4				1	2	1		0
19	Dec. 23	4				2	2			0
20	Dec. 24	4				1	3			0
21	Dec. 28	3			2	1				0
22	Dec. 29	3		2	1					0
23	Dec. 31	2	1		1					0
	1921.									
24	Jan. 1	2			1	1				0
25	Jan. 3	4	1	2	1					0
26	Jan. 4	4	2							2
27	Jan. 5	2					2			0
28	Jan. 6	2					2			0
29	Jan. 7	1					1			0
30	Jan. 8	1						1		0
31	..do....	1						1		0
32	Jan. 9	3					2	1		0
33	Jan. 10	4					1	3		0
34	..do....	2						1		1
35	Jan. 26	4			4					0
Total		113	4	4	13	14	34	25	3	16

HATCHING.

Hatching has been observed to take place at various times during the day, but in the breeding jars the majority of the thrips seem to hatch during the morning. When ready to hatch, a lidlike cap splits off at the anterior end of the egg, although it remains attached at one side. Sometimes also the egg splits longitudinally, enabling the young thrips to crawl out more easily. It emerges head first and gradually works its way out until it is able to place the front feet on the twig. It then easily draws itself out of the eggshell. When free the thrips at once crawls away in search of food and pays no attention to the empty shell. The entire process of hatching required about 2 minutes in the case of several individuals observed. The empty eggshell does not collapse, but remains intact on the twig, often for a period of several months.

FIRST-STAGE LARVA.

The young thrips begin their search for food as soon as they leave the eggs and remain active throughout their larval period. They are found in cracks and lesions of the bark and on the buds and new terminal growth. The molt takes place almost anywhere on the limbs or leaves. When ready to molt the larva becomes quiescent for a short time, after which the skin splits along the dorsum and the larva easily liberates itself from the old skin.

The first instar in summer lasted from 3 to 7 days in the case of 66 individuals, with an average of 4.05 days. In winter a longer period is required, running from 5 to 10 days, with an average of 7.9 days. Table 2 gives detailed records for the breeding work, the data for summer and winter being shown separately.

SECOND-STAGE LARVA.

Following the first molt the larvæ increase in size rapidly and are more conspicuous on the trees, owing to the prominent orange-red coloring. The larvæ in this stage are also more active and move about rath er rapidly, covering considerable areas of the host plant. When disturbed they quickly crawl around the limb, seeking a bark lesion for safety, or will go down the limb into the interior of the tree. The favorite feeding place seems to be on the buds and new terminal shoots, when there is any new growth on the trees. On cloudy or rainy days, however, or during a period of cold weather the thrips are seldom seen on the leaves and shoots, but remain down in the bark lesions, where they feed on the cambium layer of the wood. Instances have been noted in which they have tunneled back for several inches under the bark or in the center of the limb. When ready to molt again, the larvæ go down under the loose bark or into some crack or lesion, where they pass a brief period of inactivity before shedding the larval skin.

The second stage lasts only slightly longer than the first, but show a greater individual variation. As shown in Table 2, it ranged from 3 to 11 days in summer, with an average of 4.55 days for 59 individuals, and in winter from 6 to 11 days, with an average of 7.94 days.

PREPUPA.

The prepupal stage is passed largely in some lesion under the bark and is of short duration. Although the insects in this stage are able to crawl, they show little activity and probably feed very little.

Both in this stage and also in the pupa stage which follows they are never seen on the leaves and limbs and can be found only by digging into the bark.

The duration of the prepupal stage is usually very brief, less of the life of the thrips being passed in this stage than in any other. During the warm weather most of the thrips remained in this stage only about 24 hours. No specimens in the breeding jars ran over 2 days. The average for 58 individuals was 1.17 days. During the winter months this stage was passed in from 2 to 5 days, with an average of 3.5 days. Table 2 gives detailed records on the length of this stage.

PUPA.

The pupal stage is passed entirely in seclusion in the bark lesions, and the pupæ are never seen on the outside of the tree. The thrips in this state do not move about but remain quiescent, and do not feed. After the final molt the adults emerge from the bark and appear on the limbs and buds.

The pupa stage varied from 1 to 4 days in summer, with an average of 2.89 days. In winter it lasted from 2 to 7 days, with an average of 5.35 days. Even in the colder parts of the State the pupal stage is not of very great duration, for the periods of inactivity caused by unfavorable weather are passed by hibernation of the adults.

TABLE 2.—*Duration of larval and pupal stages of the camphor thrips.*

IN SUMMER.

Record No.	Date hatched.	First instar.		Second instar.		Prepupa.		Pupa.	
		Date of molt.	Length of stage.	Date of molt.	Length of stage.	Date of molt.	Length of stage.	Date of molt.	Length of stage.
	1921	1921	*Days.*	1921	*Days.*	1921	*Days.*	1921	*Days.*
1	Aug. 11	Aug. 16	5	Aug. 20	4	Aug. 21	1	Aug. 24	3
2	...do.....	Aug. 15	4	Aug. 19	4	Aug. 20	1	Aug. 23	3
3	...do.....	...do.....	4	...do.....	4	...do.....	1	Aug. 22	2
4	...do.....	...do.....	4	Aug. 20	5	Aug. 21	1	Aug. 24	3
5	...do.....	...do.....	4	Aug. 19	4	Aug. 20	1	Aug. 23	3
6	...do.....	Aug. 16	5	Aug. 21	5	Aug. 23	2	Aug. 26	3
7	...do.....	Aug. 15	4	Aug. 19	4	Aug. 21	2	Aug. 22	1
8	...do.....	...do.....	4	...do.....	4	Aug. 20	1	...do.....	2
9	...do.....	...do.....	4	...do.....	4	...do.....	1	Aug. 23	3
10	...do.....	Aug. 16	5	Aug. 20	4	Aug. 21	1	Aug. 24	3
11	Aug. 12	...do.....	4	...do.....	4	Aug. 22	2	...do.....	2
12	...do.....	...do.....	4	Aug. 19	3	Aug. 20	1	Aug. 23	3
13	...do.....	...do.....	4	Aug. 20	4	Aug. 22	2	Aug. 24	2
14	Aug. 13	Aug. 18	5	Aug. 21	3	...do.....	1	Aug. 25	3
15	...do.....	...do.....	5	...do.....	3	...do.....	1	...do.....	3
16	...do.....	...do.....	5	...do.....	3	...do.....	1	...do.....	3
17	Aug. 14	...do.....	4	Aug. 22	4	Aug. 23	1	Aug. 26	3
18	...do.....	...do.....	4	Aug. 23	5	Aug. 24	1	Aug. 28	4
19	...do.....	...do.....	4	Aug. 22	4	Aug. 23	1	Aug. 26	3
20	...do.....	...do.....	4	...do.....	4	...do.....	1	...do.....	3
21	...do.....	...do.....	4	Aug. 23	5	Aug. 24	1	Aug. 28	4
22	...do.....	...do.....	4	...do.....	5	...do.....	1	Aug. 27	3
23	...do.....	Aug. 17	3	Aug. 21	4	Aug. 22	1	Aug. 24	2
24	...do.....	Aug. 19	5	Aug. 24	5	Aug. 26	2	Aug. 28	2
25	...do.....	Aug. 18	4	Aug. 22	4	Aug. 23	1	Aug. 27	4
26	Aug. 15	...do.....	3	...do.....	4	...do.....	1	Aug. 26	3
27	...do.....	Aug. 19	4	Aug. 23	4	Aug. 24	1	Aug. 27	3
28	...do.....	...do.....	4	...do.....	4	...do.....	1	Aug. 28	4
29	...do.....	Aug. 18	3	...do.....	5	...do.....	1	Aug. 27	3
30	...do.....	Aug. 19	4	Aug. 24	5	Aug. 25	1	Aug. 28	3
31	...do.....	...do.....	4	Aug. 23	4	Aug. 24	1	Aug. 27	3
32	...do.....	...do.....	4	Aug. 24	5	Aug. 25	1	Aug. 28	3
33	Aug. 16	...do.....	3	Aug. 23	4	Aug. 24	1	Aug. 27	3
34	...do.....	...do.....	3	...do.....	4	...do.....	1	...do.....	3
35	...do.....	...do.....	3	Aug. 24	5	Aug. 25	1	Aug. 28	3
36	...do.....	...do.....	3	Aug. 26	7	Aug. 28	2	Aug. 31	3

Table 2.—*Duration of larval and pupal stages of the camphor thrips*—Continued.

IN SUMMER.

Record No.	Date hatched.	First instar. Date of molt.	First instar. Length of stage.	Second instar. Date of molt.	Second instar. Length of stage.	Prepupa. Date of molt.	Prepupa. Length of stage.	Pupa. Date of molt.	Pupa. Length of stage.
37	do.	Aug. 20	4	Aug. 25	5	Aug. 27	2	Aug. 30	3
38	do.	do.	4	Aug. 24	4	Aug. 25	1	Aug. 28	3
39	Aug. 18	Aug. 22	4	Aug. 26	4	Aug. 27	1	Aug. 30	3
40	do.	Aug. 23	5	Aug. 27	4	Aug. 28	1	Aug. 31	3
41	Aug. 17	Aug. 20	3	Aug. 24	4	Aug. 25	1	Aug. 29	4
42	do.	do.	3	do.	4	do.	1	Aug. 28	3
43	do.	Aug. 22	5	Aug. 26	4	Aug. 27	1	Aug. 30	3
44	do.	Aug. 21	4	do.	5	do.	1	do.	3
45	do.	Aug. 20	3	Aug. 25	5	do.	2	Aug. 29	2
46	Aug. 18	Aug. 22	4	Aug. 26	4	do.	1	do.	2
47	do.	do.	4	Aug. 27	5	Aug. 28	1	Aug. 31	3
48	Aug. 19	Aug. 23	4	Aug. 28	5	Aug. 30	2	Sept. 2	3
49	do.	do.	4	Aug. 27	4	Aug. 28	1	Aug. 31	3
50	Aug. 18	Aug. 22	4	Sept. 2	11	Sept. 3	1	Sept. 6	3
51	Aug. 20	Aug. 24	4	Aug. 29	5	Aug. 30	1	Sept. 2	3
52	Aug. 19	do.	5	Aug. 30	6	Aug. 31	1	Sept. 3	3
53	Aug. 20	do.	4	Sept. 3	10	Sept. 5	2	Sept. 7	2
54	Aug. 11	Aug. 18	7	Died					
55	Aug. 12	Aug. 16	4	Aug. 20	4	Died			
56	do.	Aug. 17	5	Lost					
57	Aug. 13	do.	4	Died					
58	Aug. 14	do.	3	Aug. 21	4	Aug. 22	1	Died	
59	do.	do.	3	Died					
60	Aug. 15	Aug. 19	4	do.					
61	do.	do.	4	Aug. 24	5	Lost			
62	Aug. 16	do.	3	Aug. 23	4	Aug. 24	1	Aug. 28	4
63	do.	Aug. 20	4	Aug. 24	4	Aug. 25	1	do.	3
64	Aug. 19	Aug. 23	4	Died					
65	Aug. 20	Aug. 24	4	Aug. 30	6	Aug. 31	1	Sept. 2	2
66	do.	Aug. 26	6	do.	4	do.	1	Sept. 3	3
Average			4.05		4.55		1.17		2.89

IN WINTER.

Record No.	Date hatched.	First instar. Date of molt.	First instar. Length of stage.	Second instar. Date of molt.	Second instar. Length of stage.	Prepupa. Date of molt.	Prepupa. Length of stage.	Pupa. Date of molt.	Pupa. Length of stage.
	1920-21.	1920-21.	*Days.*	1920-21.	*Days.*	1920-21.	*Days.*	1920-21.	*Days.*
1	Nov. 20	Nov. 29	9	Dec. 6	7	Died			
2	do.	Nov. 30	10	Lost					
3	Nov. 28	Dec. 5	7	Died					
4	Dec. 1	Dec. 10	9	Dec. 18	8	Dec. 23	5	Dec. 28	5
5	Dec. 2	Dec. 11	9	Dec. 22	11	Dec. 26	4	Dec. 30	4
6	Dec. 3	Dec. 12	9	Dec. 21	9	do.	5	do.	4
7	Dec. 7	Dec. 14	7	Dec. 22	8	do.	4	Jan. 2	7
8	Dec. 11	Dec. 21	10	Dec. 29	8	Jan. 1	3	Jan. 6	5
9	Dec. 13	Dec. 23	10	Dec. 31	8	Jan. 3	3	Jan. 7	4
10	do.	Dec. 22	9	Dec. 29	7	Jan. 1	3	Jan. 6	5
11	do.	Dec. 23	10	Dec. 31	8	Jan. 3	3	Jan. 7	4
12	Dec. 14	Dec. 22	8	Dec. 29	7	Jan. 1	3	Jan. 6	5
13	Dec. 21	Dec. 29	8	Jan. 5	7	Jan. 7	2	Jan. 12	5
14	Jan. 2	Jan. 9	7	Jan. 17	8	Jan. 21	4	Jan. 27	6
15	do.	Jan. 8	6	Jan. 15	7	Jan. 20	5	Jan. 26	6
16	Jan. 3	Jan. 9	6	Jan. 18	9	Jan. 21	3	Jan. 27	6
17	do.	do.	6	Jan. 19	10	Jan. 22	3	Jan. 30	8
18	Jan. 4	do.	5	Jan. 17	8	do.	5	Jan. 27	5
19	do.	Jan. 10	6	Died					
20	do.	Jan. 9	5	Jan. 17	8	Jan. 21	4	Jan. 27	6
21	do.	Jan. 10	6	Jan. 19	9	Jan. 23	4	Jan. 29	6
22	Jan. 5	Jan. 11	6	Died					
23	Jan. 6	Jan. 14	8	Jan. 24	10	Died			
24	do.	do.	8	Jan. 23	9	Jan. 27	4	Feb. 1	5
25	Jan. 7	Jan. 15	8	Jan. 24	9	Died			
26	Jan. 20	Jan. 26	6	Feb. 2	7	Feb. 4	2	Feb. 9	5
27	Jan. 21	Jan. 30	9	Feb. 7	8	Feb. 9	2	Feb. 11	2
28	Jan. 23	Jan. 31	8	do.	7	do.	2	Feb. 14	5
29	Jan. 24	Feb. 2	9	Feb. 8	6	Feb. 10	2	Feb. 16	6
30	Jan. 9	Jan. 19	10	Jan. 26	7	Jan. 31	5	Feb. 6	6
31	do.	do.	10	do.	7	do.	5	do.	6
32	Jan. 24	Feb. 2	9	Feb. 7	5	Feb. 9	2	Feb. 14	5
33	Jan. 10	Jan. 19	9	Jan. 26	7	Jan. 31	5	Feb. 6	6
34	Jan. 12	Jan. 21	9	Jan. 31	10	Feb. 3	3	Feb. 8	5
35	Jan. 13	do.	8	do.	10	Lost			
36	do.	Jan. 20	7	Jan. 29	9	Feb. 2	4	Feb. 7	5
37	Jan. 14	Jan. 21	7	Jan. 28	7	Jan. 31	3	Feb. 6	6
38	do.	do.	7	do.	7	Feb. 1	4	Feb. 8	7
39	Jan. 19	Jan. 26	7	Feb. 1	6	Feb. 4	3	Feb. 10	6
Average			7.9		7.94		3.5		5.35

ADULT.

DURATION OF LIFE.

The length of life of the adult insects is extremely variable. A series of 20 thrips becoming adult in the winter season from November 8 to February 8 (Table 3) lived an average of 82.85 days. The longest life ran from November 12 to April 4, or 143 days, while the shortest was 28 days, January 7 to February 4. A series of 20 thrips which became adult in August (Table 3) lived an average of 98 days. The longest was 196 days, August 24 to March 8, and the shortest 41 days, August 24 to October 4. The average for these runs higher than for those maturing in winter, several of them living over four months. Field observations tend to confirm these results, for many of the thrips maturing in summer hibernate, while those maturing in winter live only long enough to start the breeding season in spring. When kept without food the insects usually lived only 2 or 3 days, with an occasional specimen lasting 5 or 6 days.

OVIPOSITION.

Portion of plant selected.—The favorite place for depositing eggs is in cracks or lesions of the bark resulting from the feeding of the larvæ or from injury from other causes. The eggs are sometimes crowded into a small crack in large numbers, as many as 100 being often observed. Some eggs are placed in the leaf axils or on leaf scars and also along the bud scales. Another favorite place for oviposition is on the end of a cut stem or limb. When trees were pruned back in experimental work many eggs were deposited on the upper ends of the stubs of the limbs. In the breeding jars in the laboratory the favorite place for placing eggs was on the cut stems. Eggs are sometimes forced down into the wood on these cut surfaces. The end of a limb from a tree which had been pruned back for experimental purposes was observed to have eggs on it, and when closely examined under the binocular it was seen that several eggs had been inserted between the layers of wood, some as deep as one-eighth inch. Another place often selected for oviposition in the breeding jars was along the stems just under the cotton surrounding them in the vials. Under natural conditions the camphor thrips will seldom lay an egg on an exposed smooth surface of a limb or leaf, but always tries to select a crack in the bark or other place which offers some protection.

Description of process.—The act of oviposition has been observed many times in the breeding jars. The eggs are quickly passed from the body and seemingly with little difficulty on the part of the female, the process usually requiring about two minutes. On one occasion a thrips was seen to crawl up to a crack on the bark of a limb which already contained 2 eggs, and place the end of her abdomen in the opening near the eggs, remaining quiet for about 30 seconds. She then turned around and brushed her antennæ over the place a few times. Again turning, she placed her ovipositor in the location selected and at once deposited the egg. Some muscular contractions were observed throughout the body, particularly in the abdomen, which was also moved up and down. The abdomen then enlarged towards the

tip as the egg moved along, the egg easily slipping out when it reached the end. The female immediately crawled away without looking at the egg. On another occasion a female crawled up to the top of a limb in a jar and immediately deposited an egg on the cut surface. Then she at once crawled away, the entire operation requiring no more than 30 seconds.

Rate of oviposition and number of eggs laid.—The rate of oviposition is dependent to a considerable extent on the weather. Many more eggs are laid on bright warm days than on cloudy or cold days. The average for 20 individuals in summer was 5.1 eggs per day throughout the egg-laying period, while in winter there was an average of 4.19 per day for 20 individuals. After a brief preoviposition period amounting to 3.2 days on the average in summer and 7.4 days in winter, the females begin egg laying. The number of eggs laid per day has varied from none up to 13 in one case, but will average about 4 or 5. As will be noted in Table 3, some females are much more productive than others, even when kept under identical conditions. In the breeding jars some insects have laid from 7 to 10 or 11 eggs per day over a considerable period. Toward the end of their life the number of eggs per day diminishes, and finally ceases, being followed by a brief postoviposition stage. This period of inactivity varied from 1 to 14 days, with an average of 4.4 days for summer and 2.7 days for winter. The average length of the egg-laying stages was 90.4 days and the average total number of eggs 463.7 in summer. For winter the average of the egg-laying stages was 73.3 and the average total number of eggs 307. The greatest number of eggs laid by an individual thrips was 684.

Table 3.—*Length of life of adults of the camphor thrips, showing length of egg-laying, preoviposition, and postoviposition periods, together with number of eggs laid.*

IN SUMMER.

Record No.	Date adult emerged.	Date first egg laid.	Length of preoviposition period.	Date last egg laid.	Length of egg-laying period.	Date of death.	Length of postoviposition period.	Total length of life.	Total number of eggs laid.
	1921.	1921.	*Days.*	1921–22.	*Days.*	1921–22.	*Days.*	*Days.*	
1	Aug. 22	Aug. 25	3	Oct. 24	60	Oct. 26	2	65	488
2	Aug. 23	Aug. 26	3	Nov. 26	92	Nov. 30	4	99	559
3	Aug. 22	do	4	Nov. 3	69	Nov. 5	2	75	484
4	Aug. 23	do	3	Oct. 24	59	Oct. 26	2	64	434
5	Aug. 24	Aug. 27	3	Oct. 29	63	Oct. 31	2	68	360
6	do	do	3	Oct. 1	35	Oct. 4	3	41	280
7	Aug. 23	do	4	Dec. 20	115	Dec. 23	3	122	496
8	Aug. 24	do	3	Oct. 4	38	Oct. 8	4	45	242
9	do	do	3	Dec. 27	122	Jan. 3	7	132	656
10	do	do	3	Oct. 14	48	Oct. 21	7	58	136
11	Aug. 25	Aug. 28	3	Dec. 15	109	Dec. 19	4	116	516
12	Aug. 24	Aug. 29	5	Mar. 4	187	Mar. 8	4	96	684
13	Aug. 25	do	4	Dec. 27	120	Jan. 3	7	131	465
14	Aug. 26	do	3	Jan. 3	127	Jan. 9	6	136	508
15	do	do	3	Oct. 29	61	Nov. 1	3	67	430
16	do	do	3	Jan. 23	147	Feb. 2	10	160	672
17	Aug. 28	Aug. 30	2	Nov. 10	72	Nov. 16	6	80	521
18	Aug. 27	do	3	Jan. 5	128	Jan. 9	4	135	578
19	do	do	3	Dec. 16	108	Dec. 19	3	114	538
20	Aug. 31	Sept. 3	3	Oct. 21	48	Oct. 26	5	56	227
Average			3.2		90.4		4.4	98	463.7

TABLE 3.—*Length of life of adults of the camphor thrips, showing length of egg-laying, preoviposition, and postoviposition periods, together with number of eggs laid*—Con.

IN WINTER.

Record No.	Date adult emerged.	Date first egg laid.	Length of preoviposition period.	Date last egg laid.	Length of egg-laying period.	Date of death.	Length of postoviposition period.	Total length of life.	Total number of eggs laid.
	1920–21.	1920–21.	*Days.*	1921.	*Days.*	1921.	*Days.*	*Days.*	*Eggs.*
1	Dec. 1	Dec. 8	7	Mar. 12	94	Mar. 14	2	103	365
2	Nov. 8	Nov. 14	6	Mar. 18	124	Mar. 19	1	131	489
3	Nov. 12	Nov. 17	5	Apr. 3	137	Apr. 4	1	143	348
4	Nov. 17	Nov. 22	5	Feb. 7	77	Feb. 8	1	82	211
5	Dec. 28	Jan. 7	10	Mar. 26	78	Mar. 28	2	90	219
6	Dec. 30	Jan. 6	7	Apr. 26	110	Apr. 28	2	119	553
7	Jan. 2	Jan. 9	7	Mar. 19	69	Mar. 21	2	78	117
8	Jan. 7	Jan. 13	6	Apr. 7	84	Apr. 9	2	92	405
9	do	Jan. 15	8	Jan. 25	10	Feb. 4	10	28	25
10	Jan. 12	Jan. 22	10	Apr. 3	71	Apr. 5	2	83	320
11	Jan. 26	Feb. 3	8	May 10	96	May 11	1	105	401
12	Jan. 29	Feb. 8	10	Mar. 20	40	Mar. 21	1	51	144
13	Feb. 9	Feb. 18	9	Apr. 29	70	May 1	2	81	251
14	Feb. 1	Feb. 8	7	Mar. 26	47	Mar. 28	2	56	253
15	Feb. 14	Feb. 25	11	Apr. 9	43	Apr. 9	0	54	341
16	Feb. 6	Feb. 11	5	June 4	113	June 6	2	120	553
17	do	Feb. 14	8	Mar. 19	33	Mar. 20	1	42	154
18	Feb. 8	do	6	Apr. 24	69	Apr. 25	1	76	404
19	Feb. 6	Feb. 11	5	Mar. 20	47	Apr. 3	14	56	260
20	Feb. 8	Feb. 16	8	Apr. 11	54	Apr. 16	5	67	327
Average			7.4		73.3		2.7	82.85	307

PARTHENOGENESIS.

Reproduction of the camphor thrips seems to be almost entirely by parthenogenesis. No males have ever appeared in the breeding jars at any time of the year. Occurring in nature rather rarely, it is doubtful if the males fulfill any necessary rôle in the propagation of the species. Large numbers of the adults captured from trees and placed together in jars have never shown any tendency toward mating. The fact that isolated females have been reared for many successive generations proves that they can reproduce throughout the year parthenogenetically. The male larvæ, which are rather conspicuous because of their purple coloring, were found most abundant in January on the trees in the laboratory yard. Some occurred throughout the spring and until June, but none were seen during the summer. These larvæ when raised to adults in jars and placed together with recently matured females were never seen to mate. Neither did these females produce any offspring which showed any purple color like the immature males. In fact a purple larva never was produced in any of the life-history work.

FLYING HABITS.

Although provided with fully developed wings, the thrips seldom fly, and flight is a small factor in the distribution of the species. The maximum flight which has been observed was only a few feet. Watson (*2*) also states that the thrips seem to be incapable of flight. On a few occasions adult thrips were seen to fly from one limb to another, but it is very doubtful if they ever attempt any long flight, such as from one field of camphors to another, and seldom even from one tree to another. In the breeding jars the adults often fly from the camphor limb to the sides of the jar, and on one occasion a

thrips which escaped from a jar flew to a window about 3 feet away. When disturbed on the trees the adults will crawl around the limb or enter some lesion rather than fly away.

The natural distribution of the species also tends to prove that flight is of little importance as a means of spreading the insects. Sometimes in borders of camphor trees along a street some trees are infested while others are entirely free. Camphor trees have remained free from thrips for several years within a few rods of an infested hedge. Trees planted on farms often remain free when the thrips occur on other farms less than a mile away. On the other hand, practically all the trees in the fields of the camphor plantations where regular cultivation is practiced are infested. This would indicate that the thrips are spread by workmen or teams much more than by flight. Probably the greatest factor in distributing the insects over the State has been the movement of infested trees and nursery stock.

FEEDING HABITS.

All portions of the tree are subject to attack by the thrips except the roots. During the periods of growth the new buds seem to be the favorite food, but later the thrips attack the young shoots and limbs and also work in the cracks and lesions of the older limbs. The greatest injury to the trees probably results from the work of the thrips in the buds. Larvæ and adults both feed about the bud scales and cause the buds to turn black and die. The entire new flush of growth on a tree is sometimes killed in this way. This type of injury is illustrated in Plate II. The tender young shoots are blackened also in spots by the punctures of the insects, as shown in Plate III. One thrips is capable of blackening a considerable area of bark in a single day by its feeding punctures. This work is done mostly by the larvæ. Although the adults are often seen running about over the leaves and limbs and cause some of the injury, they do not feed so much in exposed places as they do in the bark lesions. As the limbs grow older these blackened spots become dead areas over which the bark cracks (Pl. IV, A). Deep cracks or lesions result later, the injury often being aggravated by further feeding of the thrips on the cambium layer of the wood inside these lesions. At times this advanced stage of injury even deforms the limbs (Pl. V). When once the insects are inside of the limb they will often tunnel back for several inches by hollowing out the pith of the stem. In these secluded places the pupa stages are passed, and here also the larvæ and adults pass periods of rainy or other unfavorable weather, and even hibernate in some cases.

The camphor thrips, however, should not be charged with all the injury done to the buds. Fields of camphor trees have been observed which showed a considerable number of blackened buds and dead shoots caused by *Heilipus apiatus* Oliv. This large and conspicuous black and white weevil gouges out the sides of the stems near the tips. The entire new growth on the limb then dries up and turns black. The effect of this injury on a field of young camphor trees is similar to that caused by the thrips.

SEASONAL HISTORY.

In the warmer parts of Florida the camphor thrips is active and reproduces at all times of the year, but in the more northern parts of the State, especially at Satsuma and Waller, where the largest number of camphor trees are growing, it is doubtful if they reproduce through the winter. Professor Watson states that breeding ceases at Gainesville during the winter. Adults are known to hibernate there, and it is difficult to find young larvæ during the colder months. Such is not the case at Orlando, however. The breeding experiments recorded in this bulletin were conducted through the winter at the laboratory in Orlando but under natural climatic conditions. Checks and daily observations made on trees growing in the laboratory yard have confirmed the results as given, and show that the thrips exist in all stages throughout the year.

During the late fall and winter months the thrips were especially abundant on the trees at Orlando, perhaps more so than at any other time of the year. On April 1 fewer thrips were noted, and they continued to decrease in numbers for about two months. The same condition existed at the camphor plantation at Satsuma. During April and May very few thrips were in evidence, and the camphor growers reported that they were never injurious at that time of year. During June they began to appear in considerable numbers and caused injury to the trees, being found mostly on the young buds, many of which were blackened and killed. The thrips continued to work on the trees throughout the summer, feeding on the bark when there are no buds or new growth. At Satsuma their activity ceases about November and little breeding takes place until March, unless spells of warm weather occur during the winter. At Orlando, however, they continued to live and increase on the camphor trees throughout the winter

It was always observed that no thrips were in evidence on the trees on a cold morning. When the temperature was down to 50° F. they remained down in the bark lesions on the older limbs. It was not until the sun had warmed up the atmosphere that they would come out on the bark and leaves to feed. By cutting open the lesions the insects could be found in all stages. They feed there on the bark and cambium tissues and often remain for several days at a time if weather conditions are unfavorable. In fact it is in these lesions that the adults hibernate through the entire winter in the northern part of the State. Cloudy or rainy weather even in summer has a tendency to drive the thrips to the shelter of the bark lesions. They show a decided positive reaction to sunlight and are found in the tops of the trees on bright days only.

HOST PLANTS.

As far as is known, the camphor thrips will live only on the camphor tree, *Cinnamomum camphora* (L.) Nees & Eberm. Experiments were conducted to determine if it would live on other closely related trees, including bays (*Persea* spp.), avocado, *Persea americana* Mill., and sassafras, *Sassafras variifolium* (Salisb.) Kuntze. These are included with the camphors in the family Lauraceae and are native in the parts of Florida where the camphors grow. It was thought

that the camphor thrips might have been a native insect living on some of these trees, and had taken to the camphor because of their close botanical relationship. No evidence to support this theory has been found, however.

BAYS.

Efforts were made to rear the camphor thrips on twigs of bay trees cut and brought into the laboratory, using the same type of cage as previously described for the life-history work on camphor twigs (fig. 6). The results of this work are given in Table 4, which shows the length of time each lived. Three species of bays were used, the swamp bay, *Persea palustris*, the red bay, *P. borbonia*, and the shore bay, *P. littoralis*. Observations were made on the scrub bay, *P. humilis*, in its natural habitat, but trees of this species were not available near the laboratory where they could be used for experimental feeding.

TABLE 4.—*Length of life of camphor thrips when fed on bay-tree twigs (1920–21).*

[a=adult; l=larva; p=pupa.]

Date.	Number placed on bay.	Died.
Dec. 14	5 a, 5 l	Dec. 27, 1 a, 4 l; Dec. 30, 1 p; Jan. 3, 1 a; Jan. 6, 1 a; Jan. 8, 1 a; Jan. 10, 1 a.
Dec. 14	5 a, 5 l	Dec. 20, 2 l; Dec. 22, 3 l; Dec. 24, 2 a; Dec. 27, 1 a; Dec. 29, 1 a; Dec. 30, 1 a;
Dec. 30	4 a, 4 l	Jan. 4, 4 l; Jan. 11, 3 a; Jan. 18, 1 a.
Jan. 18	4 a, 4 l	Jan. 22, 4 l, 1 a; Feb. 2, 1 a; Feb. 8, 1 a; Feb. 10, 1 a.
Jan. 18	4 a, 4 l	Feb. 8, 3 a, 4 l; Feb. 10, 1 a.
June 8	3 a	June 13, 1 a; June 16, 2 a.
June 22	4 a	June 27, 4 a.
July 5	2 a	July 9, 1 a; July 11, 1 a.
July 5	8 l	July 9, 3 l; July 11, 1 a, 3 l; July 12, 1 l.
Aug. 4	5 l	Aug. 11, 4 l; Aug. 15, 1 a.
Aug. 4	4 a	Aug. 7, 1 a; Aug. 11, 3 a.
Aug. 23	9 l	Aug. 24, 4 l; Aug. 26, 5 l.

The data in Table 4 show that camphor thrips larvæ can not live on bay-tree cuttings. In a few cases they became adult, but most of the larvæ died after a few days. The adults lived longer, one of them reaching 23 days. In nearly all of the cages the adults laid some eggs, but more of them were on the cotton stoppers than on the bay-tree twigs. In only a very few cases did any eggs hatch, and the young larvæ could not then be found. They evidently died from lack of proper food.

Thrips were also placed in cages tied over limbs of a growing bay tree. On March 15, 1921, 5 cages containing 20 thrips each, in all stages, were tied on limbs of *Persea palustris*. On opening the cages, April 6, some adults were found in one cage only. No eggs or larvæ were present. June 4 the cages contained no thrips in any stages. They evidently failed to reproduce on the bay tree.

A similar experiment was performed later on the same tree. Three small wire cages were tied on limbs of the tree on August 12, and a dozen thrips liberated in each. After 6 days they were opened and no live thrips or eggs could be found in any cage.

On May 6 several cages containing a dozen thrips each were tied on limbs of the shore bay, *P. littoralis*, at Daytona Beach. After 7 days one cage was found to have a few live adults, but on May 28 no thrips or eggs could be found in any cage.

On July 7 a wire cage was placed over a small bay tree, *P. borbonia*, planted near the laboratory, and several thrips in all stages released in it. Many more thrips were added to the tree at intervals of every few days until September 10. In no case were any live thrips found on the tree more than one day after releasing them.

All of these experiments prove that the camphor thrips will not live on bay trees for any length of time. The adults in a few cases have survived for a short time, but they will not reproduce and maintain themselves there.

AVOCADO.

The avocado, being a close relative of the camphor tree, was also tried as a food plant. Cuttings from the limbs were used as food in the same manner as in the experiments with camphor and bay twigs. The results as recorded in Table 5 are similar to those obtained with the bay. Most of the larvæ died before becoming adult. The adults lived a maximum of 31 days. Although many eggs were laid in the cages and a few of them hatched out, the young larvæ would not live on the avocado and soon died.

TABLE 5.—*Length of life of camphor thrips on avocado (1920–21).*

[a=adult; l=larva; p=pupa.]

Date.	Number placed on avocado.	Died.
Dec. 23	3 a, 5 l	Dec. 31, 2 l; Jan. 7, 1 l; Jan 10, 2 l; Jan. 17, 2 a; Jan. 20, 1 a.
Dec. 23	5 a, 5 l	Jan. 6, 1 a; Jan. 8, 1 a; Jan. 10, 2 a, 1 l; Jan. 15, 2 a; Jan. 17, 2 a; Jan. 23, 1 a.
Dec. 30	4 a, 4 l	Jan. 11, 2 l; Jan. 12, 1 a; Jan. 18, 1 a; Jan. 21, 3 a; Jan. 22, 1 a.
July 5	1 a. 1 p	July 8, 1 a; July 12, 1 a.

A large number of camphor thrips were placed on a small avocado tree in the laboratory yard, but after two days all had disappeared. Other avocado trees are growing in a row of camphor trees which are infested with thrips, but have never been found to have any thrips on them.

On March 7 some cages containing both adults and larvæ from camphor trees were tied over limbs of a large avocado tree. After one month the cages were opened and one of them was found to contain 2 young larvæ of the camphor thrips. These larvæ certainly had been reared from eggs laid by the adults in the cages. Three weeks later, however, no thrips could be found in the cage, and it was concluded that the camphor thrips can not maintain itself on the avocado tree.

SASSAFRAS.

In a similar manner efforts were made to feed camphor thrips on sassafras, also a tree closely related to camphor. The results were similar to those recorded for the bay and the avocado. Practically all the larvæ died before reaching maturity, and the greatest length of life for the adults was 30 days. Most of them died after about two weeks. A very few eggs were deposited, but in no case did any of the larvæ hatching therefrom live.

OCOTEA.

Another genus closely related to Camphor is Ocotea, which is represented in the southern part of Florida by the lancewood, *Ocotea catesbyana* (Michx.) Sarg. Professor Watson found that efforts to feed camphor thrips on this plant met with negative results. The larvæ died in 48 hours and the adults lived only a few days. He also made an extended search of the trees in their natural habitat and found no thrips on them.

OTHER PLANTS.

Some thrips were fed on orange and oak branches also. On orange an adult lived 23 days and several larvæ from 4 to 12 days. On oak several larvæ lived also for 10 or 12 days, and adults for longer, one as long as 24 days. In neither case did they lay any eggs on the plants. These experiments show, however, that life can be maintained for a short time on almost any kind of plant food. Even when fed on dead camphor wood, one adult lived for 21 days, although most of them died in a very few days. When confined in jars without any food the thrips always died in less than a week. Eggs, however, were sometimes laid on the cotton stoppers. Checks were conducted on all these experiments by feeding thrips on live camphor wood under the same conditions, and in every case they were alive when the experiments were terminated.

NATURAL ENEMIES.

The camphor thrips is known to be the prey of lady-beetles (family Coccinellidæ) and doubtless has other insect enemies, both predacious and parasitic. A lady-beetle larva was found feeding upon the immature thrips on a camphor tree, and when confined in a vial ate both larvæ and adults. No specific determination of this predator was possible because the larva died before reaching maturity. An adult of the lacewing fly *Crysopa oculata* Fab. was found in a cage over a small camphor tree and no doubt had fed on the thrips. Several dead specimens of camphor thrips collected in the field and some found in the breeding jars had been attacked by a fungus, but it is not known whether this fungus was the cause of their death. Two insect enemies of the closely related bay thrips, *Cryptothrips laureli*, doubtless prey upon the camphor thrips also. These are an internal hymenopterous parasite, *Tetrastichus* sp., and a predacious bug, *Anthocoris* sp.

CONTROL MEASURES.

SPRAYING.

As the camphor thrips spend the greater part of their life within the cracks and lesions of the bark and in other protected places, it usually is impossible to reach them with any spray material. Even the most thorough application when applied at a high pressure will have no effect on them when in these protected places. As a result a satisfactory control can not be obtained by spraying, although on warm bright sunshiny days, when the adults and larvæ are feeding on the buds and young leaves and running about over the trees, it is possible to obtain a fair percentage of mortality by spraying.

The camphor thrips can be readily killed with a solution consisting of ½ pound of 40 per cent nicotine sulphate, 2 quarts of potash-fishoil soap, and 2 quarts of lime-sulphur solution to 50 gallons of water. This spray will kill all thrips which are hit by it. If it is applied when the insects are present on the foliage in the greatest abundance, it will reduce their numbers to a large extent. The addition of the lime-sulphur solution and soap gives the spray combination a greater penetrating power than the tobacco extract alone and this seems to be an essential quality.

On August 15, 1921, a row of camphor trees was sprayed with this spray combination. The spray was most thoroughly applied at 200 pounds pressure and the trees were drenched both inside and out. The sun was shining brightly at the time and the temperature was about 90° F. A large number of thrips were in the buds and on the foliage, but of course many of them were also in the bark lesions. On the following day, August 16, an examination showed only 1 dead larva and no living thrips, either adults or larvæ, on the buds or new growth. On August 19, four days after the spraying had been done, a very careful examination was made. No live thrips were found on the leaves or buds, but 1 living adult and 2 living larvæ were cut out of the limbs. Several dead adults were also seen, some in cracks and lesions and others on the limbs. There is no doubt that the spray killed all the adults and larvæ that it hit, but of course some of the insects were so thoroughly protected in the bark lesions that they could not be reached. On August 22 a further examination showed that practically all of the thrips in the buds had been killed. The examination showed only 1 live adult and 1 first-stage larva. It should be stated, however, that a heavy rain took place on August 21 which may have washed some of the insects away. On unsprayed trees in adjoining rows not more than 10 feet away many times more living thrips were present than on the sprayed row. Prof. J. R. Watson (*3*) also has had satisfactory results in killing the insects with this spray.

Although it is generally admitted that the nicotine in the foregoing combination spray is the killing agent, it appears that the addition of lime-sulphur solution produces a much higher mortality. On June 17 a row of camphor trees abundantly infested with camphor thrips was thoroughly wet, both inside and outside, with a spray containing 2 pounds of potash-fishoil soap and 1 pound of 40 per cent nicotine sulphate to 50 gallons of water. The morning was bright and the temperature high, and many thrips were feeding on the buds and crawling over the branches. On examination, within 10 minutes after the spray had been applied, several of the thrips seemed to be paralyzed. They were on their backs and kicking but were still alive. The limbs were still wet and the thrips were held in the liquid. At the expiration of an hour, when the spray had dried, 7 dead adults were found, besides 5 living adults, 5 dead larvæ, and 10 living larvæ. Some of the live ones were kicking and it was doubtful if they would recover. After three hours, however, many living adults and larvæ were present on the trees. At 1.30 in the afternoon, or five hours after the spraying, many living adults and larvæ were also found. There were not so many adults as in the morning, but some of them may have crawled back into the lesions in the bark. On the following day there appeared

to be practically as many adults and larvæ present as on the unsprayed checks and no dead insects were found. On June 21, which was a bright, warm day, several adult thrips were found in the space of a very few minutes. They continued to feed on the young shoots and the spray apparently did them little or no harm. It was very obvious that this spray, without the lime-sulphur solution, was not satisfactory. It was much less effective than when the lime-sulphur solution was added.

Several experiments were also conducted to determine the effect of the lime-sulphur, tobacco, and soap combination spray upon the camphor thrips eggs. On August 23 twenty-three eggs which had been deposited August 22 and 23 were dipped in some of the solution which had been used for spraying the camphor trees. On August 27 no eggs had hatched. Two days later the eggs still had not hatched, but appeared to be in perfect condition. The checks at this time were hatching. On August 30 all the treated eggs were broken and found to be dried out or to contain a partly developed embryo. All of the eggs were dead. Again on August 31 a limb containing camphor thrips eggs of various ages was dipped in the same solution. Some of these eggs were hatching on the day they were treated. September 1 two eggs hatched and each of the larvæ was found dead near the eggshell from which it had emerged. On September 2 no eggs hatched. From September 3 to 5 a few eggs hatched and the larvæ were found crawling on the limbs. Of the eggs present on August 31 only a small percentage hatched. The dipping tests certainly indicate that practically all eggs which are wet by the spray will fail to hatch. The check eggs all hatched in the normal time. Where the main object is to kill the eggs, it would be advisable to make the solution somewhat stronger than that used in these tests.

Several experiments were conducted in dusting infested camphor trees with lead arsenate, calcium arsenate, flour of sulphur, flowers of sulphur, dry lime-sulphur, and Bordeaux powder. These dusts were used both separately and in various combinations with each other and with lime, but in all cases positive killing effects were lacking. Dusts containing nicotine sulphate were not available at the time.

PRUNING.

Under the system of pruning as practiced on semicommercial plantations, in which the growth was cut back without regard to the location of the nodes, or the trees were dehorned at a height of from 4 to 6 feet (Pl. IV, B; Pl. VI, A), the pruning not only was injurious to the trees but stimulated their growth so that they were not resistant to cold. This method also seemed to produce an unlimited food supply for camphor thrips, and following such pruning they appeared in countless numbers. It was obvious that a different system of pruning must be adopted which would avoid not only the direct injury to the camphor trees but also the secondary damage caused by the thrips.

The method consists of cutting off the trees at the level of the ground. This eliminates the dying back of the cut ends due to branch pruning, avoids the injury which might follow low temperatures, and destroys the food supply and breeding places of the cam-

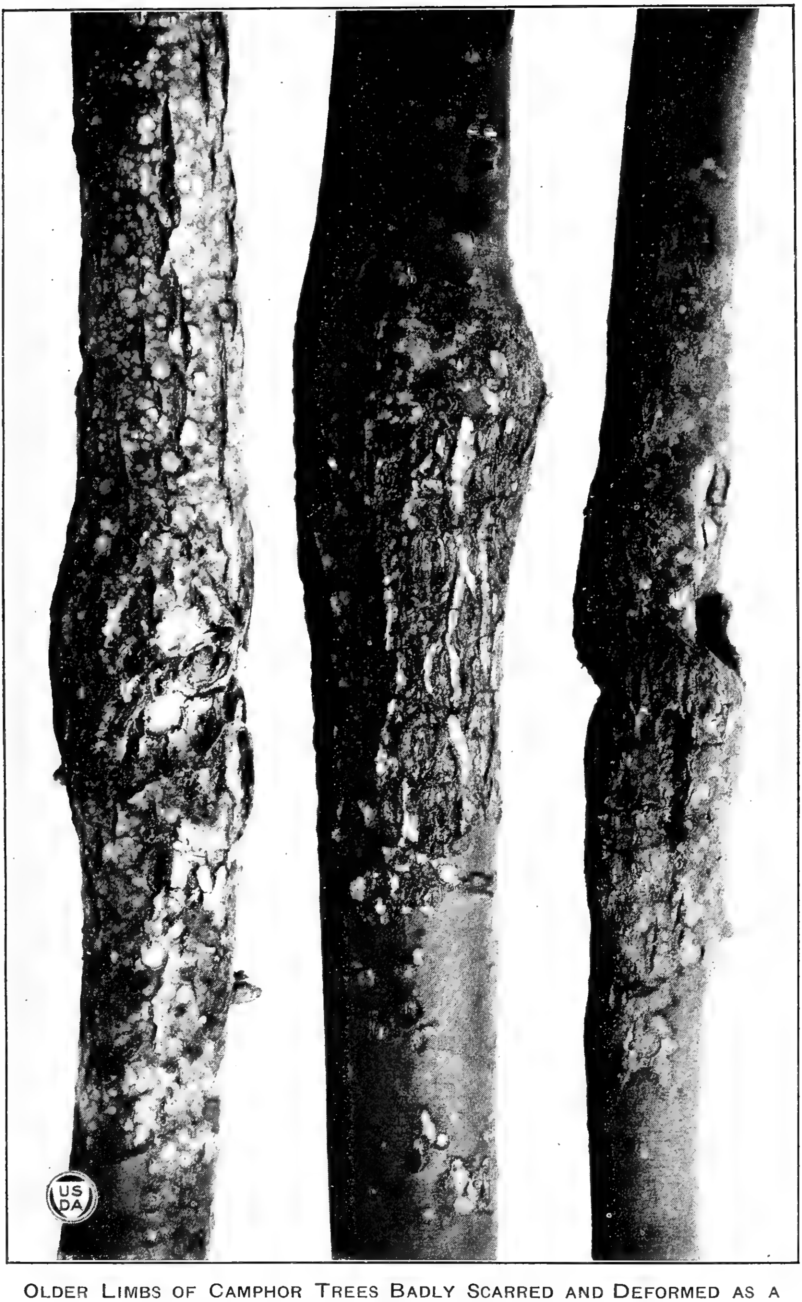
phor thrips. Without a single exception all trees cut near the ground sent up shoots from the crown, and in no instance did these shoots originate near the cut end of the stump. It is the nature of the trees to sprout from the crown instead of from any other place on the body of the tree. After a year or more these sprouts became rather large and vigorous and showed practically no damage from thrips. (Pl. VI, B; fig. 7.)

The camphor trees on a 60-acre tract at Satsuma were cut off at the level of the ground in November. The tops were not removed immediately, however, but were allowed to remain a few days after being cut down. This probably permitted some of the insects to reinfest the field. Neither were all of the small shoots growing near the base of the trees cut off, and they furnished a food supply for such insects as escaped from the cut tops. The work, however, was done on a

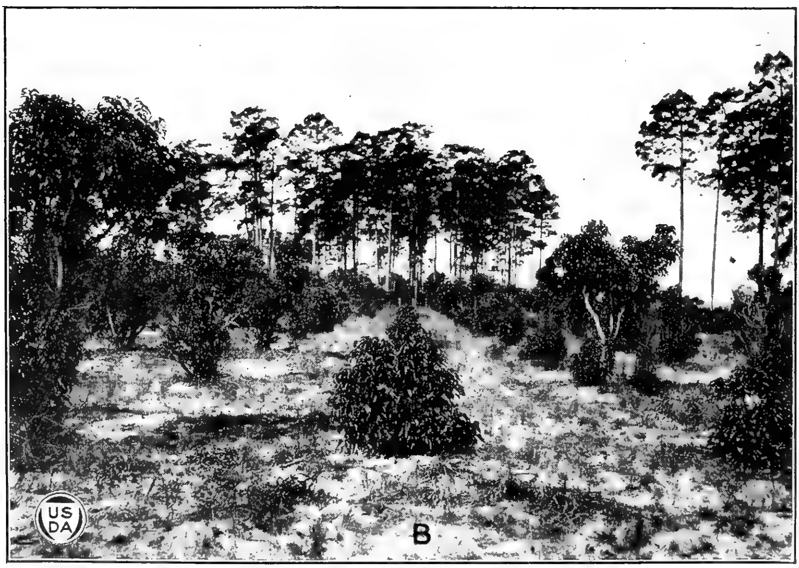
FIG. 7.—A field of camphor trees three months after being cut off at level of ground. The new growth originates at the crown and grows rapidly.

good commercial basis and no doubt was carried on as efficiently as could be expected. Repeated visits to this field showed that every tree sent forth sprouts from the crown and about a year afterward these were from 5 to 7 feet high. To be sure, some injury from thrips was noticed, but the damage was very slight. The greatest injury was on those trees located nearest the old unpruned trees across the road. The stumps were not treated with any material to prevent wood decay or kill thrips.

Pruning experiments were also conducted in a 10-acre field which had three sides not bordered by camphor trees. The trees in this field, also, were cut down at the level of the ground and all tops removed at once. All small shoots growing near the base of the stump were likewise carefully destroyed. In so far as was possible all sources of reinfestation from insects within the field were removed. Repeated visits to this field showed that all trees put forth sprouts from the crown and after the expiration of a year had attained a



OLDER LIMBS OF CAMPHOR TREES BADLY SCARRED AND DEFORMED AS A RESULT OF INJURY FROM THE CAMPHOR THRIPS.



EFFECTS OF DIFFERENT METHODS OF PRUNING CAMPHOR TREES.

A, field of camphor trees soon after being dehorned. This is an injurious system of pruning. *B*, two methods of pruning. The row in the center has been cut at the level of the ground and new growth has followed. The rows adjoining were improperly pruned and little new growth followed.

height of from 5 to 7 feet. They also appeared thrifty and vigorous. During the first three or four months after pruning no thrips were found nor any evidence of their presence. Very little damage was done to either the buds or branches during the first six months after pruning. After the expiration of more than a year there was some evidence of their presence, but the injury from them was so slight as to be of no importance whatever. Their presence in such small numbers has not interfered with the development of the trees in the least.

On this 10-acre block a great variety of tree-wound paints, varnishes, grafting waxes, and wood preservatives were used. None of these were of any value whatever in preventing reinfestation by thrips or in assisting the tree to produce more vigorous sprouts. In fact, the two rows treated with the wood preservative were injured to a considerable extent and did not send out shoots until several months after the untreated trees or those treated with other materials.

Additional experiments were conducted at Orlando to determine the effect of pruning at different times of the year on the growth of the trees and also to observe the relation of such pruning to the increase of the thrips. Thirteen rows of camphor trees averaging about 4 feet in height and planted in the form of a hedge were used for this experiment. One row was left unpruned for a check. Each month for a year, beginning in October and ending in September, one row was pruned. One-half of each of the pruned rows was cut on the level of the ground and one-half was cut exactly 1 foot high. Observations made throughout the year showed very plainly that those trees cut at the level of the ground during the winter months put forth much more vigorous and extensive growth than those cut the same way during the hot spring and summer months. The row of trees pruned during December seemed to have better growth than those cut during any other month of the year. At the end of a year all those trees pruned during the previous winter months had attained the same height that they were before being pruned to the ground and looked as well as the check row which was unpruned. The trees pruned during the summer did not attain the same height during that year but they came back in reasonably good shape also.

The half rows cut 1 foot from the ground gave results similar to those cut to the ground. The experiment showed that the winter months are unquestionably the best time to prune the trees. The trees pruned in the winter put forth much more vigorous growth and the growth came much sooner after the pruning than on those trees pruned during the summer. In this case the rows pruned during January and February were superior to those pruned during any other month. On the rows pruned during the hot summer months the sun scalded the exposed leaves and also killed the new shoots put forth from the cut ends. Hence there was little new growth until fall.

Although there was an abundance of thrips on the unpruned check throughout the year, except perhaps during March and April, no insects or injury were ever observed on the young growth on any of the trees cut at the level of the ground. The thrips, however, did much damage to the trees pruned 1 foot high. The injury was most severe on the half row pruned during the month of October, but there

was also considerable injury on the rows pruned in November and December. The least damage was noted on those trees pruned during the hot summer months. The thrips have a habit of congregating in large numbers along the sides of the stubs near the cut ends. They also lay large numbers of eggs on the cut surfaces. Hence these cut limbs are soon killed and are unable to put out new growth.

This experiment, like those previously recorded, showed that pruning the trees to the level of the ground results in much less injury from thrips and also produces a more vigorous growth then when the trees were pruned by the branch method.

TREATMENT OF ORNAMENTAL HEDGES.

When grown for ornamental hedges, it is often desirable to prune camphor trees frequently and thus keep the hedge in regular formation. Since this will result in injury from the pruning and also in subsequent injury by the thrips, some experiments were conducted on camphor hedges to determine whether they could be treated to prevent dying back and also to prevent much of the large infestation of thrips which usually follows pruning. A row of trees averaging about 4 feet in height were cut 1 foot from the ground on December 29. The cut ends of one-third of the row were treated with commercial or painter's shellac and one-third with concentrated lime-sulphur solution and nicotine sulphate containing 40 per cent nicotine, diluted 1 to 200. The remaining one-third of the row was left without any treatment whatever, as a check. As was to be expected, the thrips soon deposited enormous numbers of eggs on the cut ends of the untreated trees, but no eggs were deposited on the treated trees. The trees treated with shellac did not die back at all and after a few months put forth new growth near the cut ends. The shellac prevented the cut ends from drying out and consequently there were no unsightly dead branches. The lime-sulphur solution and nicotine sulphate treatment also prevented the trees from dying back to a large extent, but the growth started a little nearer the ground. The untreated trees also put forth vigorous growth, but the shoots were very close to the ground and unsightly dead branches were present in great abundance.

Therefore, if it is desirable to prune an ornamental hedge of camphor trees so that they will retain their beauty, it is advisable to treat all of the cut ends possible with some material that will seal them up and prevent their dying back and also prevent the thrips from ovipositing there. Shellac has proved to be the best material for this purpose.

FUMIGATION.

With the end in view of preventing the spread of camphor thrips on nursery stock and small camphor trees, some fumigation experiments were carried on to find a safe and effective method of treating the trees. Previous work along this line reported by Berger (*10*) and Newell (*7*) (*9*) showed that scrubbing and dipping the trees with soap, oils, and other insecticides is not entirely satisfactory. Many of the adults, larvæ, and pupæ can be destroyed in that way, but some of the eggs are so protected in the bark as to escape injury. The fumigation experiments were intended, therefore, to destroy the eggs in the bark lesions.

On October 20, 1921, four lots of 10 eggs each, deposited the same day, were fumigated with hydrocyanic-acid gas, two other lots being kept as checks. The four lots were placed in an airtight fumigatorium with a capacity of 25 cubic feet and subjected for two hours to a charge of gas produced from materials used at the strength of 1 ounce of sodium cyanid, 2 ounces of sulphuric acid, and 4 ounces of water to 100 cubic feet of space. After fumigation the limbs containing the eggs were removed and placed with the checks in the laboratory. The following day no effects could be noted on the eggs. On October 27, or seven days after treatment, the eggs were still unchanged and the check eggs were hatching. On October 28 all the checks had hatched. The experiment was discontinued October 31, since none of the fumigated eggs had hatched. No change in their appearance could be seen, but when broken they were found to contain a watery fluid, with no evidence of an embryo.

A similar experiment was performed on October 21, using 1 ounce of sodium cyanid and an exposure of one hour. The results were similar, no eggs having hatched up to October 31.

On November 1 another lot of eggs were fumigated, using one-half ounce of sodium cyanid to 100 cubic feet of space and an exposure of one hour. The checks all hatched on November 9 and 10. None of the treated eggs hatched, a few appearing shrunken and dried out after several days, but most of them remaining unchanged in appearance and containing a watery fluid. A final experiment was made on November 1, using two lots of eggs of about 40 each, which were fumigated for one hour at the rate of 1 ounce of sodium cyanid to 100 cubic feet of space. On November 7 a few of the eggs were shrunken and collapsed. By November 12 all the checks had hatched but none of the treated eggs hatched, nor did they contain any live embryos.

In all these experiments there was 100 per cent mortality of the eggs. Not a single egg remained alive after the fumigation. Results from the various dosages and exposures used did not differ appreciably. A strength of one-half ounce of sodium cyanid killed the eggs as well as stronger dosages. For commercial practice, however, it is recommended that the trees be exposed for one hour in an airtight fumigatorium to gas produced at a strength of 1 ounce of sodium cyanid to 100 cubic feet of space. The experiments prove that nursery stock can be entirely freed from the camphor thrips in all stages by this treatment.

Further experiments with living nursery stock showed that the trees will stand this treatment without any serious damage. On cut limbs the bark turned black after a few days and dried out sooner than it normally would, but on living camphor trees which were defoliated and well pruned back there was no apparent deleterious effect. In fact some of them withstood a dosage of 2 ounces of cyanid and an exposure of two hours.

Fumigation of course would not be practicable on commercial camphor plantations, nor would it be possible to use it on large ornamental trees and hedges. It is recommended only for nursery stock or small trees when removed from the ground for transplanting.

SUMMARY.

The camphor thrips first appeared in 1912 as an enemy to the newly developing camphor industry in Florida. At that time large acreages of camphor trees were being planted to produce a commercial supply of camphor gum. The tree was also being widely grown for its ornamental value, both individually and in hedges. The thrips appeared in enormous numbers when the trees were cut back to obtain wood for distillation, and also when ornamental hedges were pruned back in conventional shapes. The injury is not confined to pruned trees, but much more aggravated cases follow such treatment.

The thrips collect in large numbers on the stubs of the cut limbs and then attack the new shoots as soon as they appear. The buds are also attacked in the spring and at other times when new growth appears. By feeding on the buds and tender tips the insects cause them to become blackened and die back. Feeding also takes place along the limbs, with the result that the bark becomes blackened and cracks. Later these injured areas become enlarged by the thrips working down into the wood, even causing deformed limbs at times.

The camphor thrips probably is of Oriental origin, and not native to Florida, as was originally supposed. The bay trees of the genus Persea were believed for a time to be the native host of the pest, but the thrips which lives on the bay trees has been definitely shown to be a distinct species. Repeated efforts to rear and establish the camphor thrips on bay, avocado, and other closely related trees were unsuccessful. Its activities are confined entirely to camphor trees. The insect now occurs in practically all parts of Florida as well as in adjoining States where camphor trees grow. It reproduces rapidly, the generations requiring about 20 days in summer and 40 days in winter. The adults lay an average of 463 eggs and often live for several months.

The most practical method of control is a changed system of pruning the trees. Cutting the trees off at the surface of the ground rather than dehorning or cutting away part of the limbs eliminates most of the damage. This system removes all hibernating places of the thrips as well as their source of food. The trees later sprout out from the crown and the new growth resulting remains free from infestation for several months.

If done at the proper time, good control can be obtained by spraying with the following solution: ½ pound of 40 per cent nicotine sulphate, 2 quarts of potash fish-oil soap, and 2 quarts of lime-sulphur solution in 50 gallons of water. Since the thrips have the habit of hiding in the cracks and lesions of the bark during cool or cloudy weather it is recommended that spraying be done on a bright, sunshiny day. The maximum number of thrips will then be found feeding on the leaves and buds and other exposed places. This method of control will be found practicable only where a few trees are being grown for ornamental uses, since the cost would be prohibitive on a commercial camphor farm.

When it is desirable to cut back camphor hedges, a material such as shellac applied to the cut ends will prevent their dying back and will also prevent the thrips from ovipositing there.

Infested nursery stock can be fumigated with sodium cyanid at

the rate of 1 ounce to 100 cubic feet, with an exposure of one hour, with safety to the trees and absolute control of the thrips in all stages.

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October 20, 1923.

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CONTENTS

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DAMAGE TO RANGE GRASSES BY THE ZUNI PRAIRIE DOG.

By Walter P. Taylor, *Biologist, Division of Biological Investigations, Bureau of Biological Survey,* and J. V. G. Loftfield, *Assistant Ecologist, Carnegie Institution of Washington.*

CONTENTS.

INTRODUCTION.

That native rodents cause heavy losses both in cultivated crops and in forage plants on the pasture and range has long been recognized. Indeed, after a careful calculation, the Biological Survey has conservatively estimated the losses in crops in the United States at $150,000,000 annually, and in forage plants on the open range at a like sum—a total annual loss of $300,000,000 from this source (Nelson, 1918, p. 2, and 1919, p. 5; Taylor, 1920, p. 283; Bell, 1921, p. 423).[1] Determinations under controlled conditions of the actual damage done by rodents, either in cultivated crops or on the open range, are, however, almost wholly lacking. The first paper dealing in a precise manner with such damage is that of W. T. Shaw (1920),[1] who made a determination of the destruction of wheat by the Columbian ground squirrel (*Citellus columbianus* Ord) in eastern Washington. No comprehensive published results dealing quantitatively with rodent damage on the open range have been seen.

The difficulties in the way of this kind of experiment, while not small, are by no means insurmountable; and it is believed that esti-

[1] Literature references and numbers in parenthesis refer to citations in "Literature Cited," page 15.

Note.—This bulletin is a report on a cooperative undertaking between the Biological Survey, the Carnegie Institution of Washington, the Forest Service, and the Arizona Agricultural Experiment Station to ascertain quantitatively the destructiveness of prairie dogs to stock ranges. It is for the information of stockmen and others interested in the control of rodent pests of the range.

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mates of damage will be more accurate and convincing when based on controlled field tests. The difficulties include lack of information regarding the life histories of the animals concerned; necessity for evolving new methods of fencing, organization, and administration; expense of adequate fencing and inspection; and remoteness of the field of operations from headquarters.

The most important of the species of rodents which narrow the margin of profit of the farmer and stockman in the Western States are prairie dogs, ground squirrels, pocket gophers, and jack rabbits. Among these, none does greater damage to range grasses than the prairie dog, referred to more than 20 years ago as "one of the most pernicious enemies to agriculture" (Merriam, 1902, p. 263). Hollister (1916, p. 7) writes: "Prairie dogs are unquestionably responsible for great annual damage to crops and pasturage. In certain areas the destruction amounts to virtually the entire forage. Crops of grain and cultivated hay are often entirely ruined unless drastic preventive measures are taken." But "in other out-of-the-way places the animals do not interfere in the least with the operations of man."

Almost anyone who has had opportunity for observation will have been impressed with the destructive effect of the prairie dog on the forage grasses in the vicinity of its "towns," especially during dry years. Charles Springer, who, during the World War, was chairman of the executive committee of the New Mexico council of defense, writes (letter of January 6, 1919):

> Regarding the extent of damage done to the range by prairie dogs, opinions differ, and, of course, it depends upon the degree of infestation. In the 50,000-acre unit now being investigated and treated in the Moreno Valley, in Colfax County, the prairie dogs destroyed nearly all the grama grass, and I believe the damage to that range amounted to 75 per cent. Generally the damage done by prairie dogs in the infested areas with which I am familiar ranges from 40 or 50 per cent to 100 per cent. I have seen in Rio Arriba and Sandoval Counties, and in some of the other counties, large areas rendered practically worthless for grazing purposes by these pests. It is safe to estimate that the annual damage to ranges in New Mexico has amounted to destroying the grass on more than 6,000,000 acres of the very choice grazing land of the State, the areas selected and infested by prairie dogs being generally the best grama-grass flats and draws.

In order to determine quantitatively the damage done by prairie dogs to forage grasses under different conditions, three sets of experimental areas were established during the year 1918 in northern Arizona (at Coconino, near Grand Canyon; at Williams; and at Seligman) by the Bureau of Biological Survey, the Carnegie Institution of Washington, and the Forest Service. Some of the results thus far obtained are discussed here.

The prairie dog found in northern Arizona and concerned in the experiments here reported is the Zuni prairie dog (*Cynomys gunnisoni zuniensis* Hollister). This subspecies is of wide distribution, being found in central, northern, and eastern Arizona, in central and northwestern New Mexico, and in southwestern Colorado. Its destruction of forage grasses may be regarded as fairly typical of the activities of prairie dogs in general.

The procedure in the conduct of the experiments was either to fence in the prairie dogs on a particular infested tract, or (as at Seligman) to permit free entry of prairie dogs while excluding cattle; to inclose also a contiguous area of similar size, so that it

could be held under total protection from cattle as well as prairie dogs; and then, by means of permanent meter vegetation quadrats, and in other ways, to obtain quantitative information as to the vegetation actually destroyed under grazing (1) by prairie dogs alone and (2) by cattle alone (or cattle and prairie dogs together) in comparison with (3) the amounts produced under total protection. This was accomplished by actually measuring the grasses under total protection, under grazing by prairie dogs, and under grazing by cattle; by mapping the areas on the quadrats occupied by the grasses; and by fall clipping and weighing all vegetation from certain quadrats in the areas under the different conditions.

ORGANIZATION AND AUSPICES.

The project has been cooperative from the beginning. Dr. Frederic E. Clements, of the Carnegie Institution of Washington, has given valuable assistance and advice relative to the organization and prosecution of the experiment and has made provision for the charting of the vegetation. Former supervisors Ira T. Yarnall and James A. Scott, of the Tusayan National Forest, extended many courtesies in connection with the work; and the present supervisor, George W. Kimball, has continued quarterly inspection of the areas and assisted in other ways. Dr. Chas. T. Vorhies, of the University of Arizona, charted the quadrats in the spring of 1919; and D. A. Gilchrist, Biological Survey rodent-pest director for Arizona, assisted by Ben E. Foster, supervised the fencing of the areas, made check-counts of the prairie dogs in the inclosures at different times, inspected the areas at intervals, arranged for the capture and reintroduction of prairie dogs, and provided for necessary eradication. The writers have participated in the organization and conduct of the experiment from its inception and have inspected the areas at least once each year, checking up on the rodent relations, measuring the grasses, charting the vegetation quadrats, and clipping, weighing, and photographing the grasses from the clip quadrats.

VEGETATION AFFECTED.

The region in which prairie dogs are chiefly found is in the western part of the Great Plains formation, called by Clements (1920) the mixed prairie. This consists of two components, a tall grass and a short grass. Over the greater part of the area occupied by this formation the two occur mixed, but toward its eastern border the short grasses become of minor significance, while on the western they are of major importance. The "tall grass" is characterized by the presence of wheat grass (*Agropyron*) and porcupine grass (*Stipa;* usually the needle-and-thread grass *Stipa comata*), and the "short grass" by blue grama (*Bouteloua gracilis*). There are several additional associates of both components, but only those occurring in northern Arizona are of particular interest here.

The areas covered by this investigation are in the extreme southwestern extension of the Great Plains formation already mentioned. The vegetation through most of this section is of the short-grass type and consists of blue grama associated with ring grass (*Muhlenbergia gracillima*) and black or woolly-foot grama (*Bouteloua erio-*

poda). The short-grass type is of greatest importance from the forage standpoint when the blue grama is present in quantity, and of least importance when it is associated with much ring grass. The woolly-foot grama is a characteristic desert grass and is therefore of increasing importance toward the west and south, disappearing altogether at higher elevations and toward the east.

The tall grasses have nearly all disappeared from vast areas in northern Arizona as a result of heavy overgrazing, the sand dropseed (*Sporobolus cryptandrus*) being the only one which is still widespread and which will come back readily if conditions permit. In certain favorable areas the western wheat grass (*Agropyron smithii*) is still predominant, and such areas are of great importance, because of the excellent quality and large quantity of the forage produced. This wheat-grass type is especially important also because wheat grass withstands grazing and trampling by cattle very well in the situations where it has survived, and because the type contains sand dropseed, which recovers quickly if given opportunity.

The two types of grassland mentioned (the tall grass, characterized by the western wheat grass; and the short grass, characterized by blue grama) are the most important of those found grazed by prairie dogs in this region. The other types occur in washes which flood to such an extent that prairie dogs can not colonize them, on rocky hills where these rodents can not dig burrows, or in parks in the upper plant formations where the animals can not live. The short-grass and tall-grass forage types belong essentially to the same formation and were originally much more closely associated. The coming in of man with his herds of grazing animals has caused them to segregate and form distinct consociations, or forage types (Clements, 1920; Loftfield, 1924).

The experimental areas were established during the early spring of 1918 by the writers, assisted by D. A. Gilchrist. After an extensive survey, the Coconino area was selected as a typical representation of the tall-grass type, and the Seligman area of that form of the short grass most commonly found in northern Arizona. Another tract was considered in the type where blue grama is associated with ring grass, since this was more nearly representative of the short grass as it occurs generally in the Western States. An additional installation was made possible in a tract located in the short-grass type and established under Mr. Gilchrist's direction on the Tusayan National Forest, near Williams.

Summarizing, the Coconino areas are representative of conditions in the tall grass; Williams, those in the short grass; and Seligman, of the zone of transition between the Great Plains and Desert associations of the grassland climax. Results to 1922 from the Coconino and Williams areas are presented, data from the Seligman areas being omitted because experimental difficulties have so far prevented the securing of significant data on rodent damage.

THE COCONINO EXPERIMENT.

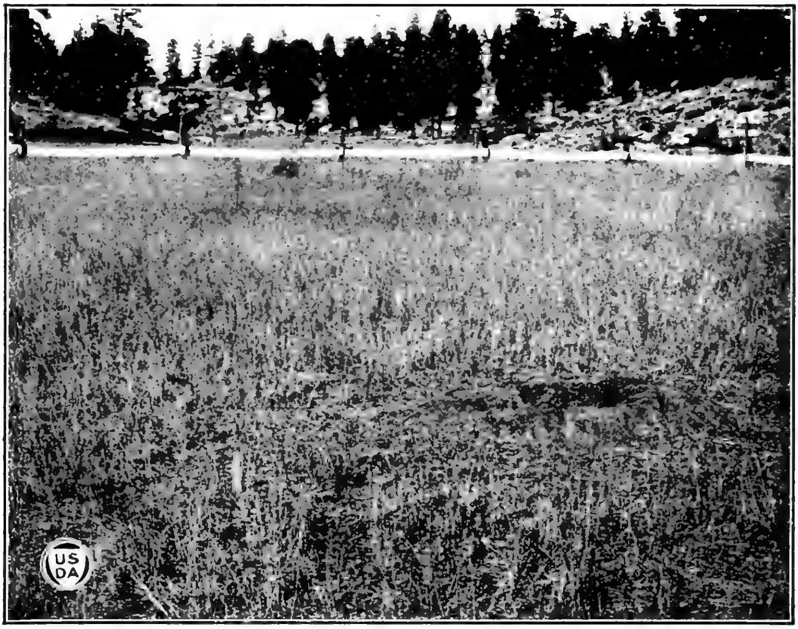
THE AREA.

The Coconino experimental tract is situated near Coconino, Ariz., in the northern division of the Tusayan National Forest, 1 mile east of the Williams-Grand Canyon road, and about 8 miles by road from

B25136

FORAGE CONDITIONS, COCONINO, NEAR GRAND CANYON, ARIZ., OCTOBER 24, 1922.

Plot of mixed wheatgrass (*Agropyron smithii*) and dropseed (*Sporobolus cryptandrus*) under total protection from grazing by livestock and prairie dogs. No ground is visible in his lot. For conditions grazed by prairie dogs and by cattle, see Plate II, Figures 1 and 2, respectively.



B25185

FIG. 1.—PRAIRIE-DOG PLOT.

The grass here is noticeably shorter and thinner than that shown in Plate I, and the ground is easily visible in several places, as a result of grazing by prairie dogs.

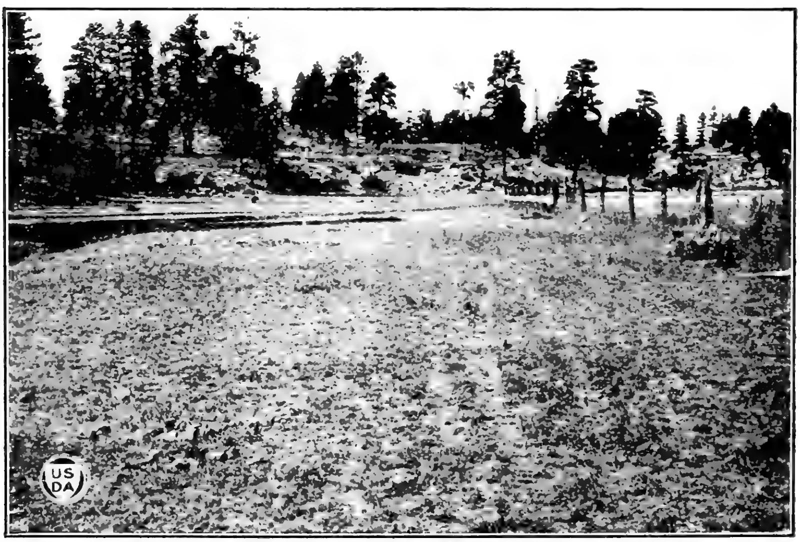


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FIG. 2.—CATTLE-GRAZED PLOT.

Very little grass is in evidence outside the fenced plots, where the forage is freely grazed by cattle.

FORAGE CONDITIONS, COCONINO, ARIZ., OCTOBER 24, 1922.

(See also Plate I.)

B21475

FIG. 1.—UNDER TOTAL PROTECTION.

The difference in the number of fruiting heads under protection and under rodent grazing indicates the difficulties of propagation by seeds when prairie dogs are present.

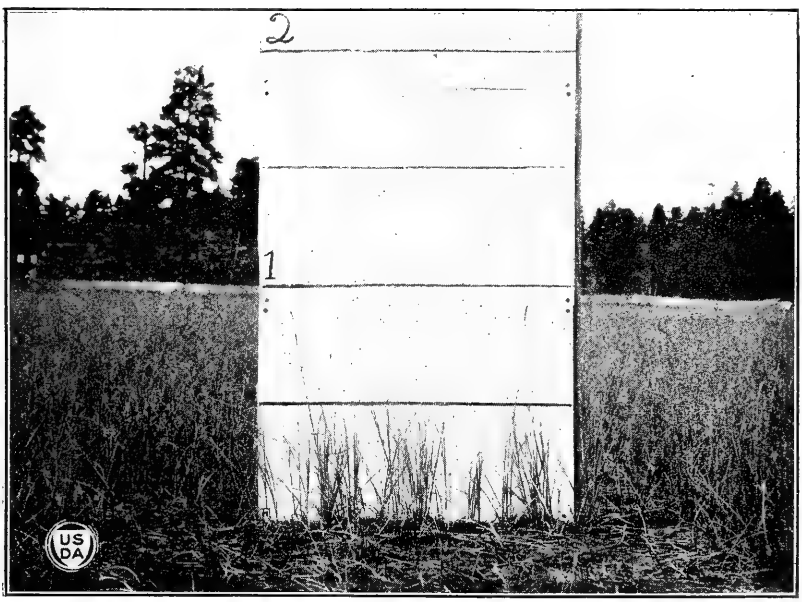

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FIG. 2.—UNDER GRAZING BY PRAIRIE DOGS.

The grass is thinner and poorer than under protection from the rodents. The background in this figure and in Figure 1 is numbered in feet.

WHEATGRASS (AGROPYRON SMITHII) UNDER TOTAL PROTECTION AND UNDER GRAZING BY PRAIRIE DOGS, COCONINO, ARIZ., OCTOBER 29, 1920.

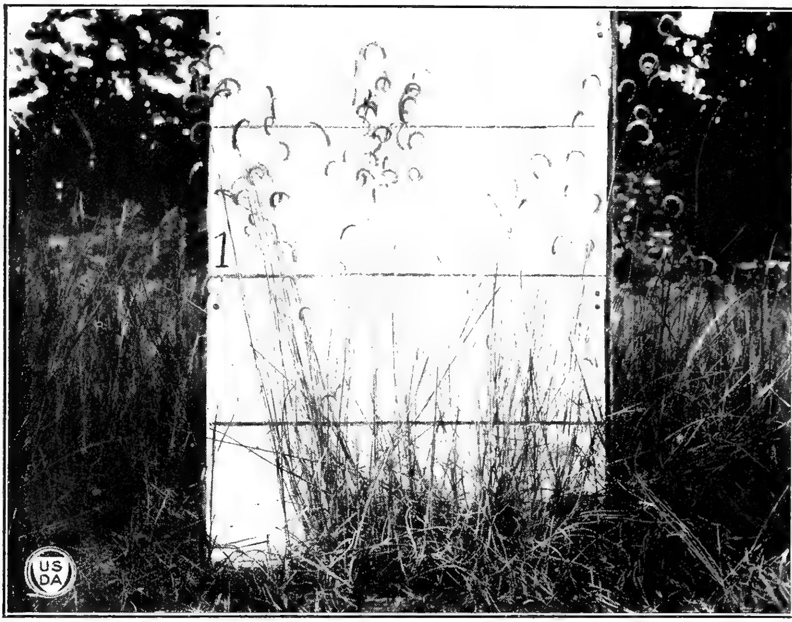

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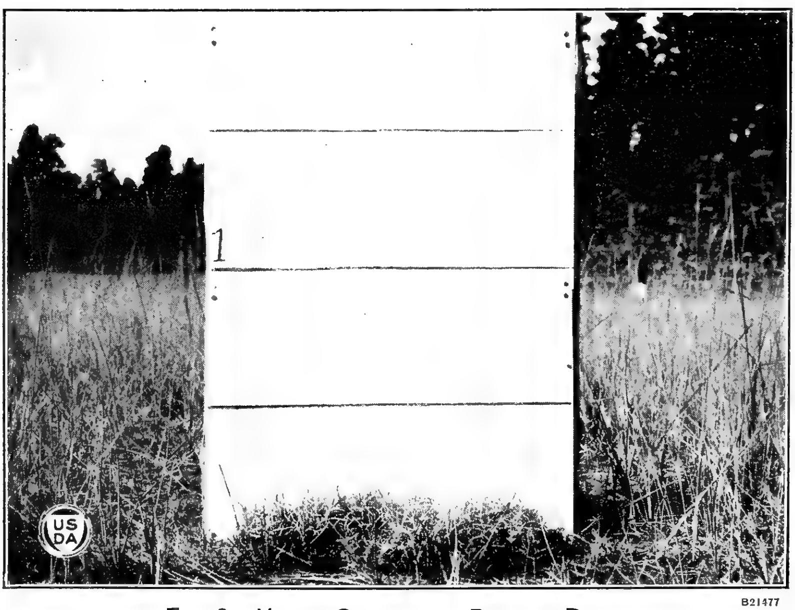
FIG. 1.—UNDER TOTAL PROTECTION.

In the plot from which prairie dogs and stock were excluded tall stems and fruiting heads developed. (Measurements in the background are in feet.)

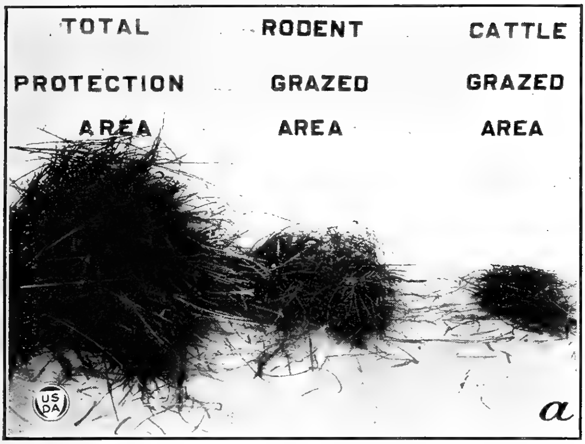


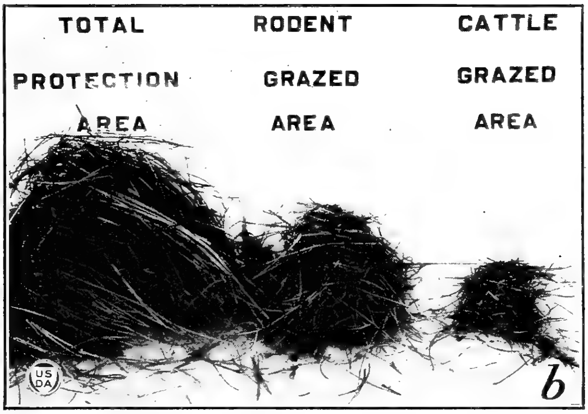
B21477

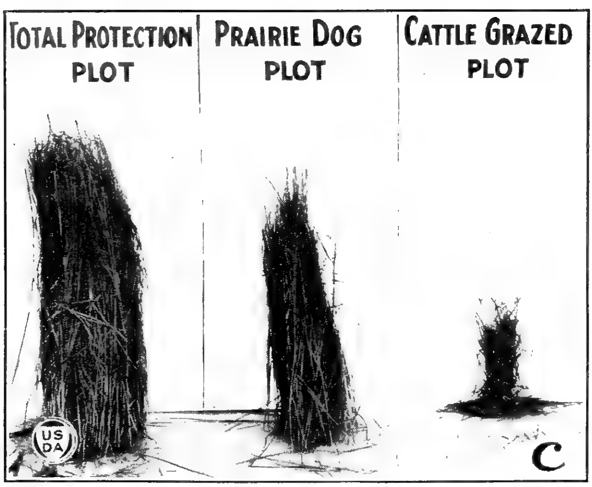
FIG. 2.—UNDER GRAZING BY PRAIRIE DOGS.

Grazing by prairie dogs usually reduces this grass to the form of a close-set turf, with few or no tall stems and frequently no fruiting heads whatever.

BLUE GRAMA (BOUTELOUA GRACILIS) UNDER TOTAL PROTECTION AND UNDER GRAZING BY PRAIRIE DOGS, COCONINO, ARIZ., OCTOBER 29, 1920.







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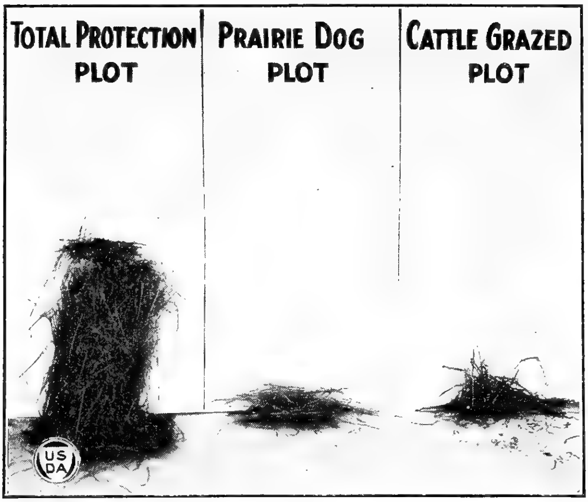
WHEATGRASS (AGROPYRON SMITHII) FROM CLIP QUADRATS, COCONINO, ARIZ.

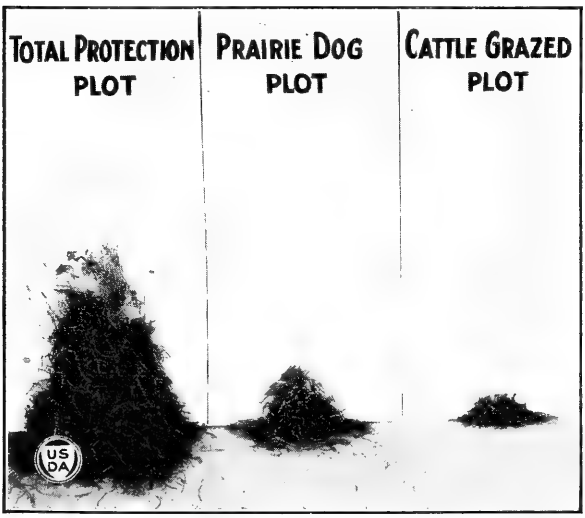
Cuttings in *a*, *b*, and *c* made after summer grazing in the years 1919, 1921, and 1922, respectively.



B25189

FIG. 1.—DROPSEED (SPOROBOLUS CRYPTANDRUS) CLIPPINGS MADE IN FALL AT COCONINO, ARIZ.

Prairie dogs here had grazed this grass even more closely than had cattle.



B25190

FIG. 2.—FALL CLIPPINGS OF BLUE GRAMA (BOUTELOUA GRACILIS) MADE AT WILLIAMS, ARIZ.

The piles labeled "cattle grazed plot" are from the open areas, where both cattle and prairie dogs grazed.

DROPSEED AND BLUE GRAMA FROM CLIP QUADRATS, 1922.

Grand Canyon post office. The place selected is in the "wash," which is best described as a water-made park in the yellow-pine forest which forms a broad belt along the south rim of the Grand Canyon at this point. The characteristic vegetation of the area (Pls. I and II) is the western wheat grass (*Agropyron smithii*) (Pl. III), sparsely dotted with bushes of the true sagebrush (*Artemisia tridentata*). The wheat grass is predominant, but where some protection permits it to produce seed the sand dropseed (*Sporobolus cryptandrus*) is of nearly equal importance. Blue grama (*Bouteloua gracilis*) (Pl. IV) is present also, but thus far has been of minor importance. Several other grasses, such as the June grass (*Koeleria cristata*), occur but are rare and of little economic importance.

Two plots were measured off on April 14, 1918, each approximately three-fourths of an acre in extent (132 by 247.5 feet). One quadrat was staked out and charted in each of the plots and another outside. The plots were fenced on May 27, 1918. To exclude stock, four strands of barbed wire were utilized. For the prairie-dog inclosure a strip of 1-inch-mesh galvanized wire 3 feet wide was used in addition, the lower 6 inches being buried in the ground, leaving 2½ feet above the surface as a barrier to the rodents.

Careful counts indicated the infestation of prairie dogs in this region to be about 25 individuals to the acre. A like proportion, or 18 or 20 animals, were found to have been fenced in the inclosure. Prairie dogs in the total-protection area and outside the inclosures were eliminated by thorough poisoning. Some difficulty was experienced in retaining the rodents where needed and in excluding them from "protected" areas, and this constituted a source of error in the experiments, but these, tending to minimize rather than exaggerate the results, show the damage as less extreme on the areas than probably would otherwise have been the case.

Two quadrats, one in each fenced plot, were added to the first three on May 19, 1919, by Doctor Vorhies, who charted the quadrats at that time. These, and the one outside, were clipped at the end of the growing season that year and each year thereafter, the results being shown in Table 1 on page 8.

PROGRESS OF THE EXPERIMENT.

When the inclosures were first fenced on May 27, 1918, the grasses, under the combined grazing of stock and rodents, had been cropped off short throughout the region, so short, in fact, as to make identification of the different species difficult. By November 13, 1918, however, certain noteworthy changes had taken place. The grasses under total protection were knee high. The forage in the rodent inclosure was in good condition also, though plainly showing the effects of rodent work. Around one series of burrows within this inclosure a circular area about 40 feet in diameter had been almost entirely grazed off by the rodents. Fifteen or twenty feet seemed to be about the average radius of intensive prairie-dog damage, though it was evident that some rodent grazing had been done over the entire area. Outside the fences, where stock had been grazing freely, the grass was cropped short, resembling its condition when the fences were first installed.

Changes in the vegetation were measured quantitatively by means of five permanent quadrats, two in each of the fenced areas and one outside. These were charted every year at the end of the growing season and one quadrat in each of the three plots clipped at that time and the crop of grass weighed by species. The results thus measured were striking, and show in a very marked manner not only the differential effects of rodent and cattle grazing, but the responses of each of the grasses to such grazing (Pls. V and VI).

In 1918, when the first three quadrats were installed, the sand dropseed (*Sporobolus cryptandrus*) was almost extinct, appearing in only one of them. This was due largely to its great palatability, both cattle and prairie dogs seeking it and grazing it to the ground at all times. The established plants were holding on in some measure by producing a crop of short leaves close to the ground in the manner characteristic of the blue grama, which enabled them to survive in spite of close grazing by cattle. But plants near the prairie-dog burrows were utterly destroyed, for the rodents had grazed the grass down to the tops of the roots, rarely leaving so much as a bud to reestablish the plant.

The chief result noted after the growing season of 1918 was the first appearance of seeding plants of dropseed in the totally protected plot. Such plants occurred in the prairie-dog inclosure also but only at some distance from the group of burrows. Very few of these plants were seedlings; in fact, nearly all may be said to have been established plants, permitted by protection to produce their first real crop of seed.

As a result of this crop, the fall of 1919 showed dropseed plants everywhere on the whole area, and from that time on this grass has been of almost equal importance with wheat grass on and around the plots. This was due to the great amount of seed produced in the protected plots scattering over the entire area and reestablishing plants where grazed out. The plants were grazed down by cattle outside the plots, however, and in the rodent inclosure, were grazed down and gradually killed so that while these plots showed at times nearly as many plants per square meter as in the protected area, clipping in fall showed little forage left.

In the spring of 1918 the wheat grass (*Agropyron smithii*) plainly showed the effects of overgrazing. This grass does not produce short leaves close to the ground as does blue grama (and also dropseed when forced to it), but sends up leafy stems which, when grazed closely, have no photosynthetic surfaces left. Such plants must draw upon stored food-material to send up short shoots which may escape and permit food supplies to be in some measure replenished. The habit of the wheat grass of spreading by rhizomes, however, is distinctly in its favor. Seeding is always a precarious means of reproduction under grazing conditions, while spreading by rhizomes permits pooling of the food produced by the few shoots which escape for the use of all shoots arising from the rhizome. The tougher texture and scabrous leaves of the wheat grass make it less palatable than either grama or dropseed, hence a few shoots at least are apt to remain untouched. When heavily grazed for some years, however, the rhizomes become starved, and

fewer shoots are produced each season. Under such conditions, sagebrush (*Artemisia*), rabbitbrush (*Chrysothamnus*), snakeweed (*Gutierrezia*), and finally annual weeds come in and tend to replace the wheat grass. All these were present on the areas during the spring of 1918. Under grazing conditions not so destructive the wheat grass is slowly replaced by blue grama. This had apparently in some measure occurred here.

Under total protection the wheat grass increased to a remarkable extent the first two years, but very slowly afterward. By 1919 a stable relationship had apparently been reached between the number and size of shoots of all grasses and the amount of water available. The year's rainfall was unusually favorable and the total amount of forage has not increased much since that time, but has fluctuated with the season. The wheat grass, however, has made consistent gains as a result of successful competition with the dropseed. Very little change has taken place in the wheat grass on the cattle-grazed area during the period of the experiment, a gradual increase occurring until 1919, probably as a result of eradicating the prairie dogs, after which time the growth fluctuated with the rainfall. In the rodent-grazed area, however, this grass showed a consistent decrease until 1922, when the amount of it practically doubled as a consequence of lessened rodent infestation.

Blue grama (*Bouteloua gracilis*) occurred in small quantities on the areas in 1918. On the cattle-grazed portion it has shown a slow consistent increase each year. In the protected plot and in the rodent-grazed plot this grass more than doubled in quantity by the end of the growing season of 1919. This, as in the case of the other grasses, was the result of protection against cattle grazing and the decrease in number of prairie dogs in the inclosure. The grama showed little change in the protected area during 1920 and decreased somewhat in 1921 and 1922, as a result of competition with the other grasses. In the rodent inclosure it continued to increase somewhat, since rodent grazing favored this grass by comparison with the others.

In 1922 (October 24) sand dropseed (*Sporobolus cryptandrus*) was found growing in the prairie-dog area somewhat more abundantly than before, indicating a decrease in grazing by prairie dogs since the last preceding inspection (fall of 1921). Needle-and-thread grass (*Stipa comata*) was found on the areas for the first time, there being an older plant surrounded by a considerable number of younger but seeding individuals as well as several seedlings. June grass (*Koeleria cristata*) was commoner this year than on former occasions. Six-weeks grama (*Bouteloua procumbens*) appeared in quantity for the first time this year as an annual, principally outside the fences. In general, the grasses did not look so well in 1922 as on previous inspections, because the rains were late. The plot under total protection was becoming weedy from lack of grazing and trampling.

TABLE 1.—*Quadrat study, giving weights of grasses clipped each fall from permanent meter quadrats under the different conditions as stated, to indicate the amount of forage destroyed by prairie dogs at Coconino, Ariz., 1919–1922.*

Kind of grass.[1]	Total-protection area.	Rodent-grazed area.	Cattle-grazed area.	Quantity destroyed by rodents.[2]
	Grams.	*Grams.*	*Grams.*	*Grams.*
Western wheat grass:				
1919	100.0	36.8	6.6	63.2
1920	117.1	24.3	8.7	92.8
1921	138.8	22.6	6.7	116.2
1922	161.1	77.2	6.7	83.9
Sand dropseed:				
1919	164.6	[3]	4.6	164.6
1920	32.8	[4]	[4]	32.8
1921	81.9	[4]	6.4	81.9
1922	38.7	3.7	6.1	35.0

[1] Blue grama did not occur in sufficient quantity to be taken into account.
[2] Obtained by subtracting amounts under rodent-grazed conditions from those under total protection. The rodents concerned are chiefly prairie dogs; a negligible quantity of forage may have been taken by others.
[3] Trace.
[4] None.

It is to be recalled that the figures in Table 1 were obtained under controlled conditions, by actual weights, and that the amount shown as destroyed by rodents is undoubtedly somewhat less than would be the case had it been possible to keep a full number of prairie dogs in the rodent inclosure and to exclude them completely from the total-protection area. The figures indicate in very general but impressive terms a potential rate of damage which may be expected where rodent grazing takes place in the wheat-grass forage type under conditions similar to those of this experiment. The following statement (Table 2) presents some of the results obtained under these conditions:

TABLE 2.—*Annual production of forage and its reduction per acre by prairie dogs.*

Forage.	Production in pounds.	Destroyed by prairie dogs.	
		Pounds.	Per cent.
Western wheat grass	1,153	794	69
Sand dropseed	709	701	99
Total	1,862	1,495	80

The annual forage loss on a section of land in this forage type at the rate shown in Table 2 would be the impressive total of 479 tons. Nowhere on the range, however, is this type the continuous vegetation cover, and in most of the region it occurs as comparatively small islands in the surrounding types. It should be pointed out also that the quantity of forage destroyed by rodent grazing does not necessarily represent the quantity actually consumed. Part of the loss is due to the reduction of vigor of many grasses through early spring grazing, which inhibits their growth and prevents them from producing the quantity of forage they otherwise would. Unfortunately, no satisfactory quantitative data are as yet available which indicate the amount of this loss. Continuous clipping of the

quadrats through the season did not yield reliable results, though check quadrats show that clipping reduces the forage and starves out the plants far more than does grazing by cattle. Trustworthy methods are now being worked out, however, which, to date, indicate that growth inhibition effects have been exaggerated. Nevertheless, allowing the 35 pounds of dry forage per day per cow, and estimating that plants weakened by average rodent grazing produce only a 50 per cent crop, the forage saved by extermination of rodents should suffice to support 37 head of cattle additional per section if forage of this type formed a continuous ground cover and if it were possible to utilize the forage when in a condition such as at the time of clipping. Of course, no extensive areas of western range afford such forage, but the figures are indicative of the quantitative reduction due to these rodents that may be expected in the best forage types, which are the ones most affected. A corresponding reduction may be expected in more typical forage.

THE WILLIAMS EXPERIMENT.

THE AREA.

The experimental tracts at Williams, Ariz., which were installed in the spring of 1918 shortly after the Coconino field test was inaugurated, are situated near the Sweetwood Ranch, 3½ miles north of the town, near the point at which the Red Lake Colony road crosses the Grand Canyon Railroad. They are in typical blue grama (*Bouteloua gracilis*) forage areas on a tract of land which slopes gradually to the west. This forage type is one of the most widely distributed in the country, being found in abundance from north of the Canadian boundary south to the tableland of Mexico and from east of the one hundredth meridian westward to the Rocky Mountains and beyond, particularly across New Mexico and Arizona. Hence the results of this experiment should be especially suggestive and of broad applicability.

A short distance from the experimental tracts is the lower edge of the juniper-pinyon formation, so that they are not far from the upper border of the grassland proper. Although this border is more favorable than the lower areas for grass maintenance, overgrazing has progressed so far that the grasses are more than half replaced already by various shrubs, as snakeweed (*Gutierrezia*) and rabbit brush (*Chrysothamnus*). The soil is composed of a fine silt produced largely from the weathering and decomposition of basalt; it is a deep reddish brown and very stony. The effects of washing are quite noticeable, the grass tufts often having half an inch or more of their roots exposed. This washing renders the grasses unusually susceptible to damage by grazing.

The Williams plots are smaller than those at Seligman and Coconino, yet large enough for the purposes of the experiment. The fenced part is 148 feet square and is divided by another fence, so that two plots each 148 by 74 feet have been inclosed. The north plot (planned for a prairie-dog inclosure) was first fenced with galvanized net wire, 1 inch mesh, 3 feet high, buried about 4 inches underground and topped with a 6-inch strip of galvanized iron, strung

around on barbed wire. Above the galvanized net wire were three barbed wires at 6 to 8 inch intervals. The south area (planned for a total protection tract) was inclosed with 6 barbed wires and with galvanized net wire, 1-inch mesh, to exclude prairie dogs. Installation was by the Biological Survey and the Forest Service jointly.

It seemed to be well-nigh impossible to confine prairie dogs in the inclosure successfully, even though an apron of galvanized net wire was later installed inside and buried in the ground in an attempt to prevent their escape; they either found some way to get out, perished from natural causes, or became the prey of predatory animals or birds. It was then concluded to try a different plan, and the north inclosure was retained as a total-protection plot instead of a prairie-dog inclosure, and by removing the galvanized net wire, the south plot was so arranged as to permit free grazing and colonizing of prairie dogs from the outside, though cattle were excluded by the barbed wire as before.

This arrangement, according to which no attempt was made to confine the prairie dogs, was found much more satisfactory than the previous one. Meter quadrats were installed on November 6, 1919, one in each of the plots, and one outside of the fences. Additional quadrats were measured off and typical quadrats were clipped for the first time on October 18, 1922, this being the first year when reliable and significant results could be obtained in this way.

PROGRESS OF THE EXPERIMENT.

The failure of earlier attempts to retain prairie dogs in their inclosure and to stop their invasion of the total-protection area prevented the obtaining of results of much value in regard to the effect of rodents on forage until the season of 1922, when (as observed during the month of October) contrasts were marked. The blue grama (*Bouteloua gracilis*) (Pl. VI) showed many seeding heads in the total-protection area, though very few were noted in the prairie-dog plot or outside. Many clumps of a tall grass, bottle-brush squirrel-tail (*Sitanion hystrix*), and a few of sand dropseed (*Sporobolus cryptandrus*) were observed in the total-protection area, while neither grass was in evidence either in the prairie-dog plot or outside the fences.

It is obvious that these grasses were enjoying far more favorable opportunities for seeding in the total-protection area than in the prairie-dog plot. The prairie dogs evidently not only destroyed an appreciable quantity, by weight and bulk, of the best forage plants, but also attacked them at their critical seeding period, thus having a markedly detrimental effect on their reproduction. The infestation of prairie dogs in the plot appeared to be about the same as, or in some cases much less than, the average infestation in the open country round about. It is felt, therefore, that the figures given are a conservative statement of actual destruction of this type of forage by prairie dogs under the prevailing conditions in the vicinity.

TABLE 3.—*Quadrat study, giving weights of grasses clipped in fall from permanent meter quadrats under the different conditions as stated, to indicate the amount of forage destroyed by prairie dogs at Williams, Ariz., 1922.*

Kind of grass.	Total-protection area.	Rodent-grazed area.	Cattle and rodent grazed area.	Quantity destroyed by rodents.[1]
	Grams.	*Grams.*	*Grams.*	*Grams.*
Blue grama	43.7	7.3	2.6	36.4

[1] Obtained by subtracting amounts under rodent-grazed conditions from those under total protection. The rodents concerned are chiefly prairie dogs; a negligible quantity of forage may have been taken by others.

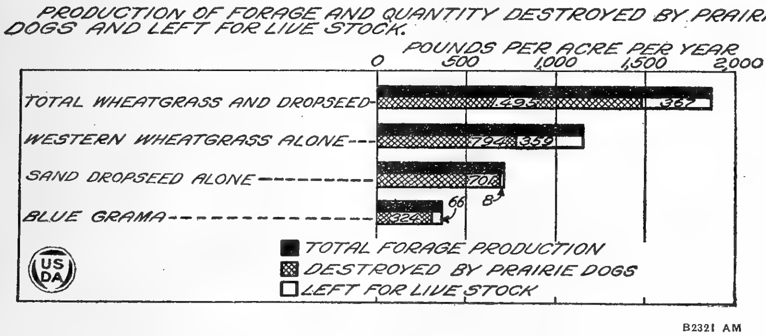


FIG. 1.—Quantitative destruction of forage by prairie dogs. Composite record from experiments of four years at Coconino, Ariz., and of one year at Williams, Ariz.

The figures in Table 3 show that under the conditions of this experiment prairie dogs destroyed the forage at the rate of 324 pounds of the 390 pounds produced on an acre in the year; or, putting it another way, rodents reduced the available stand of the blue grama—the most important forage grass in the region—by 83 per cent.

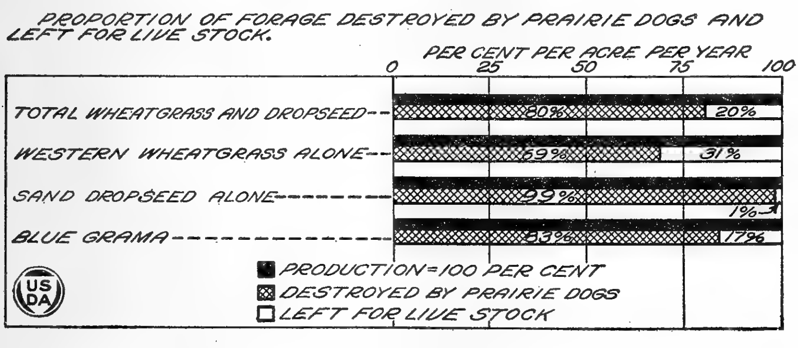


FIG. 2.—Percentage destruction of forage by prairie dogs. Composite record from experiments of four years at Coconino, Ariz., and of one year at Williams, Ariz.

SOME GRAZING RELATIONS OF PRAIRIE DOGS.

It is not the intention to imply that the rates of damage here shown actually prevail throughout the areas of the forage types here considered wherever prairie dogs are at work, for there are

many modifying conditions in different localities which may operate to increase or diminish the amount of damage. Accurate generalization covering an entire forage type can only be based on quantitative experiments carried over a period of years in several representative localities. But at the rate of damage indicated by the measured results here given, the grazing capacity of the range would almost inevitably be reduced even in a favorable year, and in a drought year the effect of rodent grazing would be critical.

Prairie dogs tend to congregate into "towns" or communities, which are occupied continuously until the vegetation is used up. The range in and around the town is severely grazed at all times, and sometimes, particularly in dry years, the grasses are grazed not only to the ground, but all the buds and even the tops of the roots are eaten, the grasses being thereby utterly destroyed. When the damage reaches this point it is spectacular and impressive.

In many localities through the Western States there exist great areas of choice range land on which the vegetation has been completely destroyed by these rodents, and usually the margin of the affected area shows a series of prairie-dog towns gradually encroaching toward the untouched grassland. The animals do not readily abandon their burrows, not in fact until the distance to the grazing area becomes too great for safety. In consequence the heavily overgrazed tracts are gone over again and again, so that by the time they are deserted there is often not one small shoot left to form the nucleus from which the range can be reseeded.

The denuded areas are sometimes wholly bare in dry season, but are usually occupied by stands of weeds altogether unfit for grazing either by stock or by prairie dogs. With the slow movement of plant succession in desert or semiarid regions, particularly under present range-control conditions, recovery from prairie-dog grazing must necessarily be slow. Complete eradication of the entire rodent population and proper grazing management does, however, give the grasses a chance to move back into the denuded area, and gradually to restore the range. It is obvious that quantitative determination of present damage to the range must be based on experiments conducted in the grassland border of an occupied prairie-dog town or in some colony where the grass has not been entirely destroyed.

It is not improbable that, under original conditions prevailing within the geographic range of the prairie dog, a practical equilibrium between the grass and the rodents had been established, so that the prairie dogs and the grasses rather constantly maintained their ranges, subject, of course, to fluctuations in climate and certain other possibly modifying factors. The coming on the scene of man, with his herds of grazing domestic animals, has completely upset this original balance and has turned the tide toward destruction of the forage plants. The killing of coyotes and other predatory animals, fully justified on certain areas where they do more damage to species of wild game and to livestock than they do good in destroying rodents, has removed one of the normal checks upon the prairie dogs and has tended still further to upset the balance. As an offset for these two modes of interference with the natural equilibrium, the Biological Survey and various cooperating agencies have undertaken systematic campaigns for the extirpation of the rodents. If utter

destruction of the range grasses over great areas is to be prevented, these campaigns must be increased in scope and number.

Careful attention to the plants eaten in the tall-grass and short-grass forage types at Coconino, Williams, and Seligman, Ariz., has shown conclusively that prairie dogs here consume only the plants eaten by cattle and do not touch plants which cattle find unpalatable. Hence these rodents compete directly with cattle for the usual forage plants of this region.

Not only do the rodents eat the same grasses, but they take them in the same order of preference that cattle do. At Coconino, for example, both eat the grasses in the following order: Dropseed, wheat grass, blue grama. At Seligman both cattle and prairie dogs grazed the Russian thistle (*Salsola pestifer*) when it was young and tender, but when old and tough neither would touch it. Prairie dogs can graze the forage much more closely than cattle, and, therefore, are able to subsist where cattle can not and are far more destructive to valuable range plants.

As previously suggested, the prairie dog does much more damage to the range during seasons of drought than at other times. Wholesale poisoning of the rodents may well increase the forage in certain instances sufficiently to permit the cattleman to carry his stock through the dry period without loss.

So far as these experiments now indicate, the prairie dog does not possess a single beneficial food habit; nor is there any argument, so far as available facts or figures indicate, against its complete eradication on all grazing ranges. The data here presented show conclusively that the comparatively small expense of eradication is more than justified.

In many overgrazed areas, apparently, total eradication of prairie dogs and reduction in the number of cattle per unit area will be necessary if the forage crop is to continue profitable. Almost anyone can realize the serious damage done when the forage plants are utterly destroyed and vast areas rendered worthless; but many stockmen do not properly appreciate the constant heavy losses to which they are subjected by prairie dogs through decreased carrying capacity of the range, even where the grass appears to be maintaining itself.

SUMMARY AND CONCLUSIONS.

To determine quantitatively the character of prairie-dog damage to the range in northern Arizona and the principal forage types affected, two sets of experimental inclosures have been established, one near Coconino, in the wheat-grass forage type; the other near Williams, in the blue-grama type. Three plots were selected in each: (1) One subject to cattle (or cattle and prairie-dog) grazing; (2) one to prairie-dog grazing only; and (3) one protected from all grazing. Grasses from meter quadrats on the plots were measured, charted, clipped, and weighed each year.

Results of four years' experiments at Coconino show that prairie dogs destroy 69 per cent of the wheat grass and 99 per cent of the dropseed, or 80 per cent of the total potential annual production of forage. Results of one year's experiments at Williams show that the

rodents destroy 83 per cent of the blue-grama crop, the most important forage grass of the region. These experiments were made under conditions where the vegetation is at present maintaining itself; in many areas the prairie dogs destroy 100 per cent of the forage and have to move out themselves. Such extreme destruction favors the growth of unpalatable weeds, makes range recovery difficult, and opens the way for soil deterioration through erosion. The prairie dog has not been shown to have a single beneficial food habit.

Prairie dogs and cattle come into direct, and, in times of drought, deadly, competition. The evidence from these experiments indicates that these rodents do not eat anything that cattle do not and that the two eat the grasses in the same order of preference; sand dropseed (*Sporobolus cryptandrus*) is preferred to western wheat grass (*Agropyron smithii*) and, when present with these, blue grama (*Bouteloua gracilis*) appears to be third in order of preference. The wheat grass apparently endures grazing by both prairie dogs and stock better than the dropseed.

The impressive total of forage that may be destroyed by prairie dogs clearly indicates the constant losses suffered almost unconsciously by stockmen who utilize the open range in places where the rodents have not been eliminated. The possible destruction of 80 per cent of the forage, or even of a far smaller proportion, is serious enough at any time, but in periods of drought it is likely to be calamitous, especially if in normal years the range is stocked to capacity. In some overgrazed areas the total eradication of prairie dogs, as well as the reduction of the number of cattle per unit area, apparently will be necessary if the forage grasses are to continue in profitable quantity.

The original equilibrium between prairie dogs and grass has been upset by man in his grazing of cattle and other livestock and in his extermination of coyotes and other predatory animals. As an offset the Biological Survey and its cooperators have undertaken systematic campaigns for the destruction of injurious rodents. Extension of such campaigns is necessary if the prairie dog is to be eliminated as a strong factor in the destruction of forage upon vast areas of good stock ranges and in reducing profits of the livestock industry there.

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DEPARTMENT BULLETIN NO. 1228

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RESULTS OF EXPERIMENTS WITH MISCELLANEOUS SUBSTANCES AGAINST THE CHICKEN MITE.[1]

By W. M. Davidson, *Entomologist, Insecticide and Fungicide Board.*

CONTENTS.

INTRODUCTION.

In connection with the enforcement of the insecticide act of 1910 a large number of proprietary insecticides and the ingredients entering into their composition have been tested against the chicken mite. A brief summary of these experiments forms the basis of this bulletin. The work was done at the Insecticide and Fungicide Board's testing laboratory at Vienna, Va., which is under the supervision of Dr. A. L. Quaintance, of the Bureau of Entomology, and under the direct charge of W. S. Abbott.

THE CHICKEN MITE.[2]

All the tests hereinafter recorded were made against the common red mite of the chicken (*Dermanyssus gallinae* Redi). The mite feeds by sucking the blood of the chickens, attacking them at night while they are roosting. It passes the day under roosts and in crevices elsewhere in the chicken house. Occasionally a few mites are found on the fowls during the day, and sitting hens are liable to attack both day and night. The mite is active in all but the coldest periods of the year and reproduces with great prolificacy. It will live for at least three months without food.

KINDS OF TESTS MADE, AND METHODS OF ESTIMATING THE RESULTS.

A few tests were made against the mites infesting sitting hens and the nest boxes occupied by them, but the great majority were conducted against mites inhabiting chicken houses, coops, roosts, and nest boxes used by laying hens only.

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[1] *Dermanyssus gallinae* Redi.

[2] For an account of the control of the chicken mite the reader is referred to Farmers' Bulletin 801, United States Department of Agriculture, Mites and Lice on Poultry, by F. C. Bishopp and H. P. Wood, and for an account of the bionomics of the chicken mite to Department Bulletin 553, United States Department of Agriculture, The Chicken Mite: Its Life History and Habits, by H. P. Wood.

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The tests included a number of materials and methods grouped under the heading "Miscellaneous treatments," besides special studies of various substances applied in the form of paints, dusts, and sprays. Details of these tests are given under appropriate headings.

In a number of cases substances were tested in small containers, such as jars and vials. Such tests, involving both contact and fumigation action on the mite, were considered so severe that failure to obtain satisfactory results thereby indicated with certainty that the materials would be inefficient in practical use in chicken houses. Such materials might, therefore, be classed as of no value, without further testing.

In computing the degree of efficiency, in tests other than in small containers, it was found necessary to use somewhat arbitrary terms. It is next to impossible to make actual counts of the mites alive and dead on a roost or in a nest box, and much more so in a chicken house. The effect of a material can be gauged only by estimating the general mortality from the percentage of living and dead found in the more easily observed places and by observing how rapidly reinfestation occurs in the premises. In the latter case the season of the year should also be taken into account, as the mite reproduces more rapidly under higher temperatures.

Many materials proved to have no value in the control of mites. Others listed as "inefficient" failed to reduce the mites sufficiently to prevent a speedy reinfestation. In some such cases it appeared that a major percentage of active mites were killed outright, but no effect was exerted on the eggs. Materials to which the term "somewhat efficient" is applied were those in which it appeared that 60 to 75 per cent of the mites were killed, but the residue was large enough to bring about a speedy reinfestation. "Moderately efficient" materials were those which reduced the infestation greatly and prevented more than a comparatively small subsequent reinfestation. The term "efficient" was reserved for materials which killed all or almost all the mites, and subsequent infestation, if any appeared, was insignificant in proportion to the original.

These terms apply only to single treatments. In many cases two or more treatments were made in the same premises. While the total mortality was increased thereby, the treatments were not progressively effective, the subsequent ones not equaling the original in effectiveness. Unless otherwise noted, the tests described herein represent single treatments.

MISCELLANEOUS TREATMENTS.

FUMIGATION.

An infested roost was fumigated in a fumigatorium of 360 cubic feet capacity for 6 hours by burning, in sawdust, 8⅔ ounces of naphthalene. A number of mites were fumigated in a tight container for 30 hours by burning the same quantity in carbon. Both treatments were effective. An infested nest box was treated by burning 13 grams of pyrethrum. A chicken house was fumigated by placing in live coals on the floor 58 cubic centimeters of a preparation containing 7.5 per cent of borax and a small quantity of pyrethrum. Two chicken houses were fumigated by burning respectively 1 and 2 pounds of sulphur for 4 hours. The capacity of the houses used in

these tests was 360 cubic feet, and they were as air-tight as the average chicken house. All the last four treatments were of little or no value.

BANDING ROOSTS.

A heavy anthracene oil applied on burlap strips at the ends of clean roosts failed to prevent the access of mites from other places in the chicken house. A few days after the application the oil hardened and the mites were able to cross it. Similar bands made of sticky tree-banding material were also inefficient, even when protection was given from the fowls by placing boards above the sticky portion of the roosts.

MEDICATED ROOSTS.

A wooden roost grooved beneath so as to fit tightly to a tin trough running the whole length of the roost and containing a coal-tar and mineral-oil mixture, when placed in an infested chicken house, repelled the mites as long as the trough contained oil to keep the wooden roosts permeated. This roost had no effect on the mites in other parts of the house (e. g., the nest boxes).

SUBSTANCES IN FOOD AND WATER OF FOWLS.

The preparations following were all without value when added to the food and water of fowls: Two lime-sulphur preparations, each containing less than 12 per cent of calcium polysulphids and calcium thiosulphates diluted at the rate of 1 to 2,150 and added to food and water for 5 and 13 days, respectively; three preparations containing from 33 to 35 per cent of free sulphur, added to each quart of food at the rate of 1 heaping teaspoonful three times a week for 6 weeks; and one preparation containing 38 per cent of free sulphur with a trace of naphthalene, used as in the preceding test but for 4 weeks only.

REPELLENT SUBSTANCES SUSPENDED IN INFESTED PREMISES.

A preparation consisting of naphthalene 14 per cent, carbon disulphid 46 per cent, and mineral oil 40 per cent, contained in a bottle with a wick, suspended from the roof of a chicken house for 2 weeks, was without value. Fifteen grams of pyrethrum (ground flowers) was suspended in a cloth bag from the top of an infested nest box. This also was of no value.

NEST EGGS, NESTING HAIRS, AND NESTING MATERIALS.

Prepared nest eggs, which are primarily designed to protect sitting hens and remain in use during the period of incubation, were used in infested nest boxes only, to determine whether they would be efficient in killing or expelling the mites.

Eight tests were made with eggs of pure naphthalene. In no case was any efficiency shown. These eggs remained in the nests for periods as long as 25 days. Their use in some instances caused marked injury to the fowls sitting on them and appeared to interfere with the health of the embryo chicks alongside them.

Five tests were made with eggs of naphthalene and paraffin mixed. These eggs were used in five infested nests for 2 hours on each of 3 days, at intervals varying from 6 to 8 days. None of these treatments was of value.

An egg containing 5 per cent of naphthalene and a small quantity of formaldehyde was used for 19 days without any effect.

A plaster egg containing a tin receptacle holding a mixture of naphthalene and sawdust was charged weekly with a mixture composed of turpentine 54 per cent, formaldehyde 18 per cent, and water 28 per cent. This egg was used for 4 weeks without any effect.

Two kinds of prepared nesting hair (fats 9.4 and 3.8 per cent, respectively) were placed in infested jars for 8 days. These proved valueless.

Two tests were made with nesting materials of shredded bark and crumbled leaves of cedar. This material was placed in clean nest boxes in mite-infested premises, and sitting hens were employed. In both cases mite infestation developed.

TREATMENT OF THE HEN.

Six hens were treated by rubbing into the skin 1 inch below the vent a preparation containing 5.6 per cent of mercury. The fowls were kept for 16 days in an infested chicken house. At the end of that time the house was still infested.

CONCLUSIONS REGARDING MISCELLANEOUS TREATMENTS.

Of the miscellaneous methods listed above only two indicated any efficiency—naphthalene fumigation and the medicated roosts.

The tests with the former were made in a fumigatorium under optimum fumigating conditions. This method would be of value where nest boxes, coops, or roosts were to be treated, but an infested house could not be treated unless very nearly air-tight. The fact that sulphur burnt at the rate of over 6 pounds to 1,000 cubic feet was quite inefficient in a chicken house at least as nearly air-tight as the average house precludes satisfactory fumigation under usual conditions.

The medicated roost was of some value, since it afforded protection to roosting fowls for a long time, but unless the rest of the premises are treated no protection is afforded fowls on the nest.

DUSTS.

In the dusting tests various makes of hand dusters were used.

The following dusts were without value under natural conditions: Air-slaked lime, Paris green, hellebore, calcium fluorid, sodium fluorid, sodium silico fluorid, barium fluorid, barium tetrasulphid, mercuric chlorid, and sulphur (refined and commercial). With the exception of calcium fluorid and mercuric chlorid none of these substances was efficient even in jar tests.

TOBACCO.

Tobacco dusts containing nicotine up to 5.26 per cent (the strongest percentage tested) were inefficient.

PHENOLS.

Dusts containing phenols up to 2 per cent were inefficient.

NAPHTHALENE.

Since naphthalene was efficient as a fumigant, it appeared that this material might have effect as a dust. Naphthalene of 40-mesh fineness was dusted in nest boxes at 100 per cent, 75 per cent, 50 per cent, and 23 per cent strengths.

In the first of these tests it was efficient, in the second and third (with wheat flour as diluent) moderately so, and in the last (with sand as diluent) inefficient. Pure naphthalene dusted on roosts was efficient in two out of four tests. A 4 per cent naphthalene in lime was inefficient in a roost test, while a 12 per cent preparation in sulphur and lime proved moderately efficient when dusted in an infested coop. Coarse naphthalene was inefficient when dusted in two infested chicken houses, while a naphthalene of 40-mesh fineness was of slight value in a third.

It appeared that naphthalene is efficient only in a small circumscribed area where it may have a fumigation effect. In more open places it has a rather weak repellent effect. Dissolved in kerosene, the mixture was not more efficient than pure kerosene, but dissolved in gasoline the resultant mixture was more efficient than pure gasoline.

In practice, dusting with naphthalene is not a feasible method for the control of the chicken mite.

DERRIS.

Four infested chicken houses were dusted with the finely ground powder of the roots of *Derris* sp. Undiluted dust was efficient in one house and temporarily so in another. In a third house a 75 per cent dust was only moderately efficient, in a fourth test a 50 per cent dust was inefficient. Flour was used as a diluent.

Derris powder is a remedy of value, but it would appear that two or more applications are necessary and that it loses its efficiency if diluted more than 25 per cent. Its action on larvæ and adult mites is first to stupefy them, the insects dropping to the ground and dying after two or three days. The material is rather unpleasant to apply.

PYRETHRUM.

Finely ground flowers of *Pyrethrum cinerariaefolium* and *P. roseum* were efficient when dusted undiluted in a nest box and when applied in a chicken house in two applications 33 days apart. Another house was dusted once and a third twice (32 days between applications). These latter tests showed only moderate efficiency, but conditions were very unfavorable in the house treated twice.

Pyrethrum diluted with flour to 75 and 50 per cent strengths was inefficient in chicken houses.

Pyrethrum is somewhat less efficient and less unpleasant to handle than derris-root powder.

SABADILLA SEEDS.

Finely ground sabadilla seeds (*Schoenocaulon officinale*) were efficient in treating an infested nest box.

It appears probable that this material equals derris in efficiency, but no chicken house tests were made to determine this point.

CONCLUSIONS REGARDING DUSTS.

From the foregoing it appears that of the dusts derris powder is the most efficient, that pyrethrum is of much value, that naphthalene is efficient only in circumscribed areas where a good fumigation effect can be obtained, and that ground sabadilla seeds may prove efficient but require more thorough testing.

PAINTS.

Various preparations and substances have been tested as paints, applied with a brush. A dust consisting of naphthalene 23 per cent, phenols 0.6 per cent, coal-tar hydrocarbon oils 1 per cent, tobacco dust, and siliceous material was inefficient when mixed with water to form a thick paint and applied on an infested nest box. A preparation containing coal-tar creosote oil 87 per cent (the remainder being water) was efficient when painted over the entire inside of a chicken house. Anthracene oil alone and also at the rate of 1 pound to a gallon of turpentine killed mites on roosts. Cresol in whitewash in a roost treatment was efficient at 5 per cent, but not at 2.5 per cent. Whitewash alone was inefficient.

All efficient contact sprays are of value when applied as paints if the infested premises do not contain deep cracks (which harbor the mites) into which the liquid can not be forced with a paint brush as successfully as by the spray nozzle. While roosts can be painted without much trouble, it is more satisfactory to spray nest boxes, coops, and chicken houses.

SPRAYS.

In the tests with sprays the liquids were applied with a knapsack sprayer holding approximately 5 gallons, and a Bordeaux type of nozzle was used in most instances. In some cases where roosts or coops were treated a hand sprayer was used.

SOLUTIONS OTHER THAN OILS.

Spray tests with solutions other than oils are summarized in Table 1. Some of the materials contained animal oils (whale oil), but none mineral oils.

TABLE 1.—*Results of spray materials (other than oils) against the chicken mite.*

Material.		Dilution in water.	Subject of test.	Results.
	Per cent.			
Ammonia water	28.00	1 to 9	Roost	Inefficient.
Alcohol, ethyl	95.00	None	Roost and coop	Do.
Formaldehyde	37.50	1 to 9	Chicken house, coop	Somewhat efficient.
Ferric sulphate [$Fe_2(SO_4)_3$]	42.34	1 to 9, 3 to 7	Roosts, nest boxes	Inefficient.
Sodium hypochlorite	[1] .94	None	Nest boxes	Do.
Sodium sulphur	13.87	1 to 16	Coops	Do.
Do	12.45	1 to 8, 1 to 5	Roosts	Do.
Lime-sulphur (32° B.)	34.00	1 to 15, 1 to 9	Chicken houses, nests	Do.
Nicotine sulphate [2]	41.82	1 to 600	Chicken houses	Somewhat efficient.
Do [2]	8.72	1 to 75	do	Moderately efficient.
Derris extract [2]	16.00	1 to 1,000, 1 to 500	do	Inefficient.
Whale-oil soap	80.00	1 lb. to 1 gal.	do	Somewhat efficient.
Do	80.00	2 lbs. to 1 gal.	do	Do.

[1] "Available chlorine."
[2] Whale-oil soap at the rate of 4 pounds to 100 gallons of water added.

Table 1 indicates that several well-known contact insecticides used at strengths ordinarily efficient against most sucking and some chewing insects proved inefficient against the chicken mite.

In a number of tests, sodium hypochlorite at a dilution weaker than 0.94 per cent ("available chlorine") was in all cases inefficient.

Formaldehyde, 4 per cent, did not give a killing that could be termed efficient and was objectionable to the operators.

Lime-sulphur and sodium sulphur, well-known acaricides, proved inefficient, the former even at dormant orchard strength.

Free nicotine at a strength of 0.07 per cent in combination with whale-oil soap, 4 pounds to 100 gallons, proved but slightly efficient, while at a strength of 0.12 per cent with a similar proportion of whale-oil soap it was moderately efficient.

Extract of derris, 16 per cent, diluted to 1 to 1,000 and 1 to 500, with the addition of whale-oil soap, 4 pounds per 100 gallons, was inefficient.

Whale-oil soap, 1 pound to 1 gallon and at twice this strength, showed some efficiency but was hardly satisfactory.

OILS.

Tests were made with three types of oil preparations: (1) Straight oils, (2) mechanical mixtures of two oils or solutions of another type of substance (e. g., naphthalene) in an oil, and (3) oil emulsions.

Preparations of the first type included kerosene, gasoline, and coal-tar creosote oil. Pure kerosene was used in three chicken houses. In one house it was efficient; in the two others only moderately so. Gasoline was of little value. A coal-tar creosote oil (sp. gr. 1.062 at 30° C.) was quite efficient. It appears certain that all the heavier oils, undiluted, would be efficient, but the lighter oils, perhaps owing to too rapid evaporation, are less efficient.

The tests made with mechanical mixtures are given in Table 2.

TABLE 2.—*Results of tests with oil mixtures and mixed oils against the chicken mite.*

No. of test.	Materials.	Strength.	Dilution.[1]	Result.
		Per cent.		
1	Paradichlorobenzene	100.0	960 grams in kerosene 4 gallons	Moderately efficient.
2	....do	100.0	480 grams in kerosene 4½ gallons	Somewhat efficient.
3	....do	100.0	960 grams in gasoline 4½ gallons	Inefficient.
4	Naphthalene	100.0	960 grams in kerosene 5 gallons	Somewhat efficient.
5	....do	100.0	480 grams in kerosene 4 gallons	Do.
6	....do	100.0	240 grams in gasoline 2 gallons	Do.
7	Wood creosote oil	100.0	1 to 8 in whitewash	Efficient.
8	Phenol	100.0	....do	Moderately efficient.
9	Crude carbolic acid	100.0	1 to 9 in whitewash	Efficient.
10	....do	100.0	1 to 11½ and 1 to 15 in whitewash	Inefficient.
11	Cresol Kerosene	20.0 80.0	None	Efficient.
12	Coal-tar creosote oils Phenols	86.8 13.2	....do	Do.
13	Carbolineum Kerosene	50.0 50.0	....do	Do.
14	Carbolineum Kerosene	33.3 66.7	....do	Do.
15	Carbolineum Kerosene	25.0 75.0	....do	Do.
16	Carbolineum Kerosene	20.0 80.0	....do	Do.
17	Carbolineum Kerosene	10.0 90.0	....do	Do.
18	Carbolineum Kerosene	7.0 93.0	....do	Somewhat efficient.

[1] In tests 1 to 6, inclusive, the paradichlorobenzene and the naphthalene were dissolved in the oils.

Paradichlorobenzene dissolved in kerosene and gasoline, and naphthalene dissolved in kerosene, gave no better results than the respective oils by themselves. Naphthalene dissolved in gasoline was more efficient than gasoline itself. The use of paradichlorobenzene is not advisable, as it was found to impart a taste to eggs laid after the treatment of the chicken house.

Mechanically mixed in whitewash and applied immediately, wood creosote oil was efficient when the oil comprised 11 per cent of the spray. Crude carbolic acid in whitewash was efficient at 10 per cent and inefficient at 8 per cent. Phenol was moderately efficient in whitewash at 11 per cent.

The other tests reported in Table 2 were with mixed oils. They demonstrated the efficiency of heavy tar oils. The coal-tar oil (carbolineum) used in tests 13 to 18, inclusive, had a specific gravity of almost 1.2. Such an oil evaporates much more slowly than a mineral oil of the type of kerosene.

Oils were used in the form of emulsions also. These are divisible into three types—emulsions of light mineral oil, heavy mineral oil, and coal-tar oils. In some of the second class a small quantity of coal-tar oil had been added.

Table 3 presents the tests made with oil emulsions against the chicken mite.

TABLE 3.—*Results of tests with oil emulsions against the chicken mite.*

Test No.	Nature of oil.	Composition of emulsion.					Dilution.	Result.
		Oil.	Soap.	Phenols.	Water.	Undetermined, by difference.		
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		
1	Light mineral	77.0	4.0		18.6	0.4	1 to 3	Efficient.
2	do	77.0	4.0		18.6	.4	1 to 7	Inefficient.
3	Heavy mineral	82.2	8.0		6.9	2.9	1 to 2.5	Efficient.
4	do	82.2	8.0		6.9	2.9	1 to 4	Moderately efficient.
5	do	82.2	8.0		6.9	2.9	1 to 6	Inefficient.
6	do	84.1	7.5		7.3	1.1	1 to 16	Do.
7	do	84.1	7.5		7.3	1.1	1 to 24	Do.
8	do	79.6	5.9	6.9	7.6		1 to 4	Somewhat efficient.
9	do	82.7	5.0	5.9	6.4		1 to 9	Inefficient.
10	do	82.6	4.2		13.2		1 to 3	Efficient.
11	do	82.6	4.2		13.2		1 to 4	Do.
12	Coal-tar	30.4	24.6	40.0	5.0		1 to 157	Inefficient.
13	do	41.0	22.0	30.0	5.0	2.0	1 to 32	Somewhat efficient.
14	do	41.0	22.0	30.0	5.0	2.0	1 to 99	Inefficient.
[1] 15	do	48.0	25.6	12.0	14.4		1 to 49	Moderately efficient.
[1] 16	do	50.0	22.0	16.0	8.0	4.0	1 to 24	Efficient.
17	do	63.9	21.9	7.5	6.7		1 to 12.3	Moderately efficient.
18	do	63.9	21.9	7.5	6.7		1 to 19	Do.
19	do	[2] 3.2	1.0	(2)		[3] 95.8	2 pounds to 1 gallon.	Inefficient.

[1] Box tests.
[2] Coal-tar oils and phenols 3.2 per cent.
[3] Sand and mineral pigment 95.8 per cent.

The oil used in tests 1 and 2 was kerosene. The emulsion was efficient when diluted 1 to 3 parts water.

In tests 3 to 11 the material contained a heavy mineral oil with high boiling point, and in addition a small amount of coal-tar oil was present in that used in tests 6 to 9, inclusive.

These oils were efficient when used at dilutions of 1 to 2.5 and 1 to 3 parts water.

Coal-tar oils were used in tests 12 to 18, inclusive. In tests 15 and 16 nest boxes were used and a dilution of 1 to 24 was efficient. In tests with chicken houses an emulsion of somewhat greater oil content was only moderately efficient when diluted 1 to 12.3 parts water.

The material used in the last test was a powder containing 3.2 per cent oils and phenols and 1 per cent soap. It was diluted as little as 2 pounds to a gallon of water. At this and all weaker strengths it was inefficient.

SUMMARY.

Miscellaneous treatments.—Miscellaneous treatments for the chicken mite included fumigating infested premises, banding roosts, using a medicated roost, adding substances to the food and water of fowls, placing prepared nest eggs under sitting hens, using medicated nest hairs and nesting materials, hanging up substances in infested premises, and treating hens with an ointment.

Only two of these treatments were of any value. A medicated roost remained free from mites, but the rest of the chicken house continued infested. Naphthalene burned in sawdust and carbon was efficient when used in a fumigatorium. Fumigation of chicken houses does not appear to be satisfactory. In a chicken house of average air-tightness, sulphur burned at the rate of 6 pounds to 1,000 cubic feet was inefficient.

Dust.—Materials without value in the form of dusts were calcium fluorid, sodium fluorid, sodium silico-fluorid, barium fluorid, barium tetrasulphid, mercuric chlorid, Paris green, hellebore, refined and commercial sulphur, and air-slaked lime. Used in tobacco dust, nicotine up to 5.26 per cent was inefficient, and so also were phenols up to 2 per cent in a dust carrier. Powdered derris root and pyrethrum flowers were efficient when undiluted. Naphthalene was efficient only in the case of nest boxes and not in chicken houses. Tests with powdered sabadilla seeds were insufficient. This material gives promise of high efficiency.

Paints.—Tests with materials applied as paints indicated that heavy oils, either pure or slightly diluted with lighter oils, were efficient. Cresol 5 and 10 per cent in a whitewash was of some value. A stiff whitewash alone was inefficient, as was a preparation containing 23 per cent naphthalene.

It is not so easy to penetrate to deep cracks with a paint brush as with a spray nozzle, and therefore painting houses with deep cracks is not as effective as spraying.

Sprays.—The following materials when applied as sprays to infested premises were inefficient or without value: Ammonia water, 2.8 per cent; ethyl alcohol; formaldehyde, 4 per cent; iron sulphate, 15.88 per cent; lime-sulphur (32° Baumé), 1 to 9; sodium sulphur (12.45 per cent sodium sulphid and thiosulphate), 1 to 5; sodium hypochlorite, 0.94 per cent "available chlorine"; extract of derris root, 1 to 500.

Nicotine solutions containing 0.07 per cent and 0.12 per cent free nicotine, with the addition of whale-oil soap at the rate of 4 pounds to 100 gallons, were of some value, especially the stronger solution. Whale-oil soap at 1 pound to a gallon and at 2 pounds to a gallon was also of some value.

Pure, heavy coal-tar creosote oil was entirely efficient. Kerosene was moderately efficient and under some conditions quite so, but it lacked the body and lasting effect of the heavier oils. Gasoline was of little value.

Paradichlorobenzene and naphthalene when dissolved in kerosene and gasoline were not more efficient than the pure oils themselves, except that naphthalene in gasoline gave results somewhat superior to pure gasoline.

In a whitewash, 11 per cent of creosote oil and 10 per cent of crude carbolic acid were efficient, but 8 per cent of the latter was of no value and 11 per cent of phenol was only moderately efficient. These mixtures are wholly mechanical and must be applied immediately. They are less satisfactory than emulsions or combinations of oils.

Oil mixtures of kerosene and cresol and of kerosene and carbolineum were quite efficient even when the coal-tar oils comprised only 10 per cent of the mixture. A preparation of 20 per cent of the heavier oil would insure more body to the material; in fact, the higher the percentage of heavy oil the more lasting will be the effect.

Kerosene-oil emulsion containing 77 per cent of oil was efficient when diluted 1 to 3 or 25 per cent. This gives an oil percentage in the spray of 19.25 per cent. Greater dilutions were less efficient, but two or more applications of a spray containing not less than 16 per cent of oil should be of considerable value.

Emulsions of heavy mineral oils containing approximately 82 per cent of oil were efficient at strengths of 1 to 2.5 and 1 to 3 in water, the actual sprays containing, respectively, 23.49 and 20.65 per cent of oil. Out of two tests in which the oil content of the sprays was 16.5 and 16.4 per cent, respectively, one spray was efficient and the other moderately so. Sprays with less than 16 per cent of oil were inefficient, but two applications at this strength would be of much value.

Chicken-house tests with coal-tar disinfectants were made with sprays containing as much as 4.8 per cent of oil. At this strength a single application was moderately effective. In nest boxes as little as 2 per cent of oil was efficient.

Kerosene-oil emulsion diluted to 19.25 per cent oil appeared superior to pure kerosene, perhaps because of its greater penetrating power. Emulsions of coal-tar oil diluted to 4.8 per cent oil were inferior to straight tar oils and to mixtures of coal-tar and mineral oils.

RECOMMENDATIONS.

Heavy oils from coal tar and wood tar, or such oils diluted with a lighter oil, such as kerosene, so that not less than 20 per cent of the mixture is heavy oil, will successfully control chicken mites, provided the premises are thoroughly sprayed and the material not stinted.

A heavy mineral-oil emulsion containing at least 20 per cent oil in the actual spray will be efficient under similar conditions.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

November 1, 1923.

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UNITED STATES DEPARTMENT OF AGRICULTURE

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THE STEM NEMATODE TYLENCHUS DIPSACI ON WILD HOSTS IN THE NORTHWEST.

By G. H. Godfrey, *Pathologist, Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry,* and M. B. McKay, *Associate Pathologist, Oregon Agricultural Experiment Station.*

CONTENTS.

INTRODUCTION.

Attention has been called several times to the occurrence of the stem and bulb infesting nematode *Tylenchus dipsaci* Kühn (*Tylenchus devastatrix* in most of the European literature) on various hosts in America. Byars (*1*)[1] mentioned its occurrence on hyacinth. Smith (*9*) and Byars (*2*) reported diseases in red clover and strawberry due to the organism. McKay dealt more at length with the disease in strawberry (*5*) and later reported its occurrence on alfalfa (*6*) and wild strawberry, *Fragaria chiloensis* (*7*). Godfrey (*3*) mentioned its occurrence on all the known hosts in America and briefly described the symptoms. This paper deals with the wide occurrence of the pathogen on the wild strawberry and reports an additional host, the false dandelion, *Hypochaeris radicata.* The discovery of the disease on this plant was made by Prof. H. P. Barss and the junior writer together, at Newport, Oreg., in June, 1922. *H. radicata* is listed by Massalongo (*4*, p. 8) as being subject to a nematode gall referred to as a "Helminthocecidium," which, judging from the illustration, is clearly the same as the one discussed here.

SYMPTOMS.

The symptoms of the disease on the wild strawberry (Pl. I, *A*, *B*, and *C*) are in every respect the same as on the cultivated. Swellings

[1] The serial numbers (italic) refer to "Literature cited" at the end of this bulletin.

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occur on leaves, stolons, and flower pedicels, and even in the flowers and fruits themselves. In the leaves the swellings may be in the petioles, either basally, intermediate, or involving the blade. They vary greatly in size, but are often several times the diameter of the leaf stem. The gall on the petiole is spindle shaped as a rule and often an inch or more in length. The swellings in the leaf blades are characteristically crinkled thickenings of greater or less extent, sometimes but not always made more prominent by a reddening against the green background. The leaf symptoms are not likely to be confused with those of any other disease.

The stolon symptoms are like those on the petioles. A swelling may be anywhere on the stolon, even on its tip. (Pl. I, *B*.) This undoubtedly is a factor in its distribution, the new plant in this case being affected at the outset. Fruiting stems are sometimes badly affected. Usually the galls occur most prominently as long club-shaped swellings just below the blossoms. Often the parts of the calyx or even the petals and receptacle are greatly enlarged and distorted. Fruits in all stages of maturity are sometimes irregularly swollen.

In Hypochaeris the symptoms as seen in the summer and fall consist mainly of swellings in the leaves, as they lie in a rosette on the ground. They are often distorted and twisted abnormally, especially when the gall is in the midrib. (Pl. II.) Here, as in the strawberry, a reddish coloration is sometimes evident on the leaves, but this is not the rule. Evidences of typical galls in flower stems were found as well, in the form of slight increases in thickness at their bases. Stem galls produced by an insect (*Aulax hypochoeridis* Kieff) were observed quite frequently also and should not be confused with the nematode swellings. The insect galls as a rule are much larger and more spongy in texture than those produced by the nematodes. Thanks are due to Dr. E. P. Felt, New York State, entomologist, and to L. H. Weld, of the Smithsonian Institution, Washington, D. C., for identification of the insect.

THE CAUSAL ORGANISM.

Examination of the typical swellings and galls invariably disclosed the presence in them of Tylenchus. Those from the strawberry had already been authentically identified as *Tylenchus dipsaci*. The Hypochaeris nematode appeared identical in every way with that found in alfalfa, clover, and strawberry and was so determined. Our identification was later verified by Dr. N. A. Cobb, nematologist, at Washington, D. C., who reported only a slight and insignificant variation in measurements from the other strains.

DISTRIBUTION.

The information on distribution included herewith, as well as on environmental relations, dissemination, etc., was derived principally from special survey trips made by the writers separately during the summers of 1921 and 1922. In addition, the Oregon State Board of Horticulture, prompted by the seeming advisability of conducting an eradication campaign, made an independent survey in the summer

of 1922. While these surveys were not by any means exhaustive, they covered typical localities and a considerable range of territory.

The results of the various surveys indicate that the stem nematode occurs definitely on one host or the other throughout practically the entire length of the Oregon coast line and in at least Pacific County in Washington. In addition, it occurs inland in Willamette Valley at various points. The southern limit is not definitely known for either host. On *Fragaria chiloensis* it is abundant in Coos County and also from there northward to the northern end of Tillamook County, where it apparently ceases. *Hypochaeris radicata* was found to be affected in the southern part of Lincoln County and northward, beyond the range of the diseased wild strawberries, into Washington. It was also found at Hillsboro, St. Joseph, McMinnville, and Corvallis, Oreg.[2] At the last point it occurred in considerable abundance on the campus of the Oregon Agricultural College. Material from this source was used for photographs (Pl. II) and for preserving. Cultivated strawberry fields were found infested to an extent that was of rather serious economic importance in Coos and Lane Counties and to a minor degree at Corvallis in Benton County. The distribution of the disease on its various hosts is shown on the map. (Fig. 1.)

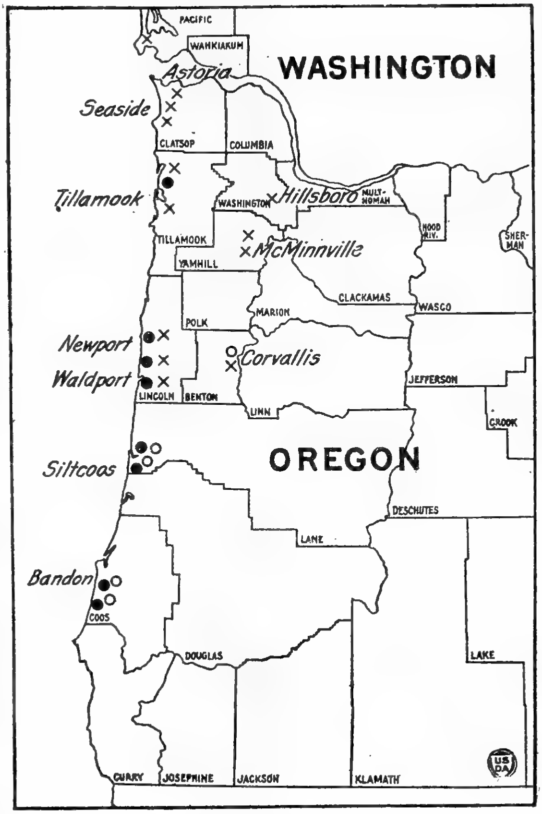


FIG. 1.—Map of western Oregon and southwestern Washington, showing the distribution of the stem nematode (*Tylenchus dipsaci*) on cultivated strawberries (○), on wild strawberries (●), and on the false dandelion (×).

APPARENT INDEPENDENCE OF THE TWO HOSTS.

During the course of these surveys several interesting facts were brought out in connection with an apparent lack of any correlation

[2] During the summer of 1923 the nema disease was found in *Hypochaeris radicata* in great abundance at different points on Puget Sound, Wash., throughout the length of Willamette Valley, Oreg., and southward along the coast as far as San Francisco, Calif.

whatever between the two hosts, in so far as occurrence of the disease was concerned.

At various places along the shore line between Waldport and Newport, Oreg., a distance of approximately 20 miles, the disease was found on both Fragaria and Hypochaeris, both of which grew in abundance. At times where the two plants were closely associated both were found affected, and again one or the other or both were free. In some spots either host growing by itself was affected and at other times free from infection. In fact, infested areas were, as a rule, in spots. The plants on one strip of considerable extent might be 50 per cent and even occasionally 100 per cent infested, while those on another strip a short distance away would be entirely free or possibly less than 1 per cent affected.

At Newport a search was made for the disease in several small patches of cultivated strawberries within the town and in its suburbs. No diseased plants were found, however, in spite of the fact that Hypochaeris was found diseased quite frequently in strawberry patches. In one case a diseased plant of Hypochaeris was found in actual contact with the crown of a cultivated strawberry plant, which itself was not affected.

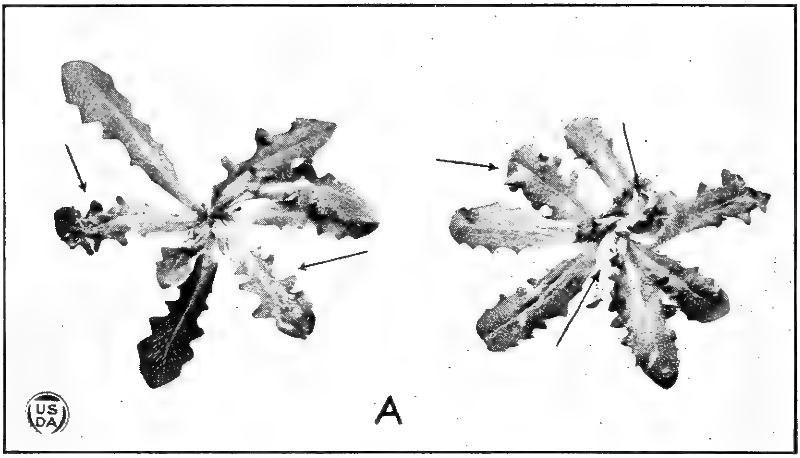
Likewise, in Tillamook and vicinity plants of Hypochaeris were found affected. Cultivated strawberry fields were observed and examined carefully, but not a trace of the disease was found. Wild-strawberry plants at this place, which is 5 miles from the coast, were examined but found free from infection.

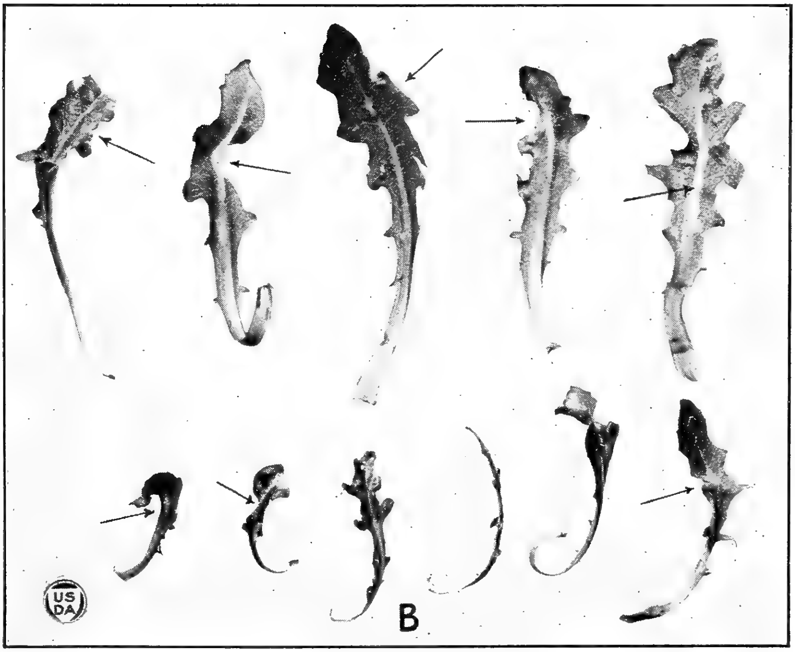
Along the Tillamook County beach the disease was found scatteringly on the wild strawberry, in some places 75 per cent of the plants being affected; in others, none or comparatively few. Hypochaeris was also quite frequently diseased, some areas one-fourth of a mile from the shore being found in which 75 per cent of the plants were affected. Such spots were rare, however. In fact, many areas were examined during the course of the surveys in which not a trace of the disease was to be found. Here, too, occasional beds of cultivated strawberries were observed and found to be free from the disease.

In the vicinity of Seaside, Oreg., and thence northward it was observed that the stem nematode occurred on Hypochaeris, but was not to be found on Fragaria. Seaside is separated from the Tillamook Beach region, where the strawberry disease occurred abundantly, by a natural barrier consisting of a high promontory which was heavily forested. For several miles this host does not grow. This natural barrier may be an explanation for the absence of the disease beyond. Between the Tillamook Beach and Seaside Hypochaeris was rather rare, but such plants as were observed were free from the disease. Great open meadows in which both Hypochaeris and *Fragaria chiloensis* grew abundantly occurred near Gearhart. Many infested Hypochaeris plants were found here, but the Fragaria was always free from the nematode. Along the edge of the golf links at Gearhart a similar condition existed. Occasional diseased Hypochaeris plants were likewise found at the branch agricultural experiment station at Astoria, Oreg. Along the coast line north and south of Long Beach, Wash., the disease was found in considerable abundance on Hypochaeris, but the wild sand strawberry was entirely free from infection. Not a trace of the disease could be

EXAMPLES OF NEMATODE INFESTATION.

A, Symptoms of the stem-nematode disease in the wild strawberry (*Fragaria chiloensis*). Note the swollen and distorted leaf blades and petioles. *B*, A new plant of wild strawberry developing on a runner which is badly swollen, due to nematode infestation. *C*, A wild strawberry leaf showing the upper and lower surfaces, with typical swellings caused by the stem nematode. *D*, Red-clover seedlings infested as a result of inoculation with the strawberry strain of *Tylenchus dipsaci*.





ROSETTES AND LEAVES OF FALSE DANDELION.

Arrows indicate the more striking points of infestation by the stem nematode: *A*, Two small "rosettes" of the false dandelion (*Hypochaeris radicata*) twisted and deformed owing to infestation. *B*, Leaves of *Hypochaeris radicata*, showing infestation.

SITES OF AFFECTED STRAWBERRY BEDS.

A, Yaquina Head, near Newport, Lincoln County, Oreg. The entire north face of the hill back of the lighthouse is covered with plants of *Fragaria chiloensis*, a large proportion of which are attacked by the stem nematode, *Tylenchus dipsaci*. *B*, Bluff at Seal Rocks, south of Newport, Oreg. On top of this bluff are beds of the wild sand strawberry severely attacked by *Tylenchus dipsaci*. *C*, A small bed of wild strawberries on the gradually sliding slope of the bluff on the north side of the hill shown in *A*. About 10 per cent of these plants are affected.

found in cultivated strawberries in northwestern Oregon or in Washington.

Quite frequently a large association of plants was found with the Fragaria or Hypochaeris, including the salal (*Gaultheria shallon*), the brake (*Pteris aquilina*), a moss, and a large number of small herbaceous flowering plants. All of these plants were carefully examined without finding any sign of the disease.

RELATION TO ENVIRONMENT.

In the case of Fragaria, nearness to the ocean appeared to be a factor which influenced infection. In most cases no disease was found 100 yards from the shore, even though it was abundant at the edge of vegetation above the beach. Quite frequently this host growing in the sand about the driftwood was affected. Again, frequently the sea side of a sand dune would have affected plants, while those on the land side would be free. Slopes near a rocky promontory upon which the waves dashed at high tide were often heavily infested. This was the case at Seal Rocks, in Lincoln County, at which point wild-strawberry patches quite extensive in area on a bluff 50 feet high were found more than 50 per cent affected with the nematode disease. (Pl. III, *B*). At Yaquina Head (Pl. III, *A*), where meadow grasses and strawberries predominate, the disease was found in great abundance, especially on the steep north slope of the hill. Over the entire slope from the beach to the summit, probably 500 feet high, diseased plants were found. Plate III, *C*, shows a view of a typical spot on the hillside where the disease was found.

A similar condition of a high percentage of diseased plants in strawberry meadows near the shore existed at another promontory known as "Jump-off Joe." Diseased plants occur close to the beach and on the side of the bluff to the very top. None was found, however, back of the edge of the bluff, a distance of 50 feet.

In many cases it appeared that almost constant high humidity was required to maintain infection and favor the spread of the disease on this host. This was obviously obtained at times by actual salt spray from the ocean and again from the heavy fog that occurs so frequently near the coast. When the photograph reproduced in Plate III, *B*, was taken, the atmosphere was saturated by a falling mist that nearly shut the distant rocks from view.

Nearness to the ocean did not appear to be a factor in the case of Hypochaeris. At Newport, where the plant grew abundantly as a weed in meadows, on lawns, and beside the streets, the disease was found for several hundred yards back into the town. It also occurred some distance from the shore in Tillamook County, Oreg., and near Long Beach, Wash. The presence of the infested Hypochaeris plants a considerable distance from the shore led to the search for and discovery of the disease at the inland valley points, where direct influence of ocean moisture could be no factor in infection.

ORIGIN AND DISSEMINATION OF THE DISEASE.

The possibility of the infection of the wild-strawberry plants having originated in the cultivated fields was at first considered

as not impossible. The infested patches first seen were close by the outlet of Siltcoos Lake, which lies about 4 miles distant, in the midst of the cultivated area. Diseased cultivated plants might conceivably have gotten into the lake and been carried down the stream. Becoming stranded, they might then have been blown or otherwise carried to the spots where the disease was observed. The abundance of the disease in remote places and in spots not easily reached in this way, however, would seem to be negative evidence. For example, a high percentage of diseased plants occurred on a sand hill about 50 feet high which was covered with vegetation.

In the light of later observations, especially, the possibility of infection having spread from cultivated fields does not seem very great. On the contrary, the results of the survey seemed to indicate that the disease has been present on the wild plants for many years and that it is passing to the cultivated strawberries. The following few cases may be mentioned specifically as apparent illustrations:

A grower living in Bandon, Oreg., set out young strawberry plants from Portland, where the disease is not known to occur, in the spring of 1920. No trouble was noticed until late in the growing season, when the nematode disease was found affecting a few plants. By October, 1921, 25 per cent of the original plants and quite a number of young plants started from the old ones were found diseased and had been pulled out and burned. The disease was found in abundance on wild strawberries within 50 feet of the cultivated patch and from there on for a distance of 2½ miles, which was as far as the search was continued.

Another grower, living just outside Bandon and within 200 yards of the ocean beach, obtained plants in 1919 from a grower in Bandon. The nematode disease developed quite heavily on this planting the first season, and in 1920 it became so severe that the entire patch was plowed up and planted to other crops. The wild-strawberry plants in the pasture adjoining, and even inside of the fence surrounding this patch, were extensively affected by the nematode disease. A visit to the patch of cultivated strawberries in town from which this planting had been started failed to reveal any evidence of the nematode disease among them, nor had the grower ever noticed any malady of the sort.

Still another grower had in 1919 moved a strain of strawberries from a farm a few miles east of Bandon, where it had been maintained for eight years without any evidence of the nematode disease, to another farm 4½ miles south of Bandon and 1½ miles back from the ocean beach. In 1920, the next season after the strawberries were moved to the new location, a slight amount of injury from the nematode disease was noticed, and in 1921, 2 per cent of the plants were rather severely affected. No wild strawberries were known to be near the berry patch east of Bandon, although they were quite numerous in the region of the farm south of town. The nematode disease has been found quite abundantly on wild strawberries at a point 3 miles from this farm. No examinations for the disease on the wild plants have been made closer to the farm than this, though there is every possibility that it does occur on the wild plants very much nearer to this farm.

Certain unusual observations related to the dissemination of the disease may be worthy of record. A plant of *Fragaria chiloensis* was

occasionally found growing entirely by itself, isolated by several feet from any others. Frequently such isolated plants were diseased as badly as those found in close association in thick beds. In one spot near Newport, Oreg., scattered diseased plants were found at the lower edge of a thick growth of salal (*Gaultheria shallon*) on the face of a perpendicular bluff. Similarly with Hypochaeris, a single diseased plant was found growing in a small pocket of soil at the edge of a jagged rock more than 4 feet distant from any other vegetation.

Nothing is known as to the chief agencies for the distribution of this disease among wild plants. Besides the gradual spread through runners or stolons, which occurs with strawberries, animals, birds, wind, water, etc., readily occur to the mind as possible agencies of dissemination. But even with these and other means active in helping to spread the pest, it seems entirely unlikely that it could have reached its present distribution during the time that it has been known to occur on the cultivated plants in the same region. In fact, as previously mentioned, the evidence seems to point to the conclusion that the pest has been present on the wild plants for many years and that it is now passing, in some localities at least, from the wild to cultivated strawberries.

It is just as possible to conceive of the nematode as a native of that region as to conceive of the many native plants as having evolved there. It is equally plausible, however, to recognize the possibility of the pest having been introduced perhaps a hundred years ago when ships sailed from northwestern ports laden with lumber and other products and came back sometimes with dirt ballast from European ports.

The interesting fact must be recorded here that *Hypochaeris radicata* is, according to Piper and Beattie (*8*), a weed that is not native to that section. It is said to have been introduced from Europe. This fact naturally adds considerably to the interest of the problem, particularly in connection with speculation as to the origin of the disease and how it has become so widespread.

INOCULATION EXPERIMENTS.

Inoculations were made as a rule by the rough but effective method of simply breaking up diseased plants containing living nematode material—eggs, larvæ, and adults—and stirring them into the soil. Careful observations showed that this releases the organisms into the soil, from which they enter immediately any host plant they may be able to infest.

Shortly after the occurrence of the disease on cultivated strawberries in the Northwest became known in 1919, diseased specimens sent to Washington, D. C., were used to inoculate *Fragaria vesca*, *F. virginica*, *F. platypetala*, and *F. chiloensis*, all of which were successfully infected. No significance was attached to this at the time, however, except in possible relation to future studies on resistance. It was not until two years later that *F. chiloensis* was found naturally infested.

Inoculations of red-clover seedlings were made at Corvallis, Oreg., with the wild-strawberry material, and typical infections were secured. In Plate I, *D*, are shown typical diseased clover seedlings

that became affected as a result of such inoculations. Attempts to inoculate other hosts with the Hypochaeris strain have thus far failed. Further inoculation experiments, designed to get some information as to the possibility of these wild strains passing over to cultivated hosts, are under way at the present time.

ECONOMIC SIGNIFICANCE.

Many different crops are subject to infection by the stem nematode, according to foreign literature. Among these are alfalfa, barley, beans, buckwheat, flax, garlic, hyacinth, narcissus, oats, onion, peas, potato, rye, strawberry, and many others of less importance. Many of these crops are cultivated in western Oregon and Washington. The general belief in Europe is that there are distinct biological strains of the nematode. It is not known at the present time whether or not the American strains can adapt themselves to new hosts. The mere fact of the existence of the disease in so many hosts seems to imply this possibility.

SUMMARY.

The stem nematode *Tylenchus dipsaci* has been found rather abundantly in the Pacific Northwest on the wild strawberry (*Fragaria chiloensis*) and on the false dandelion (*Hypochaeris radicata*).

The wild-strawberry strain of nemas occurs along the west coast of Oregon near the seashore, from Coos County to northern Tillamook County. The Hypochaeris strain was found from the southern part of Lincoln County, Oreg., to Long Beach, Wash., being almost universally present in western Oregon.

Judging from natural occurrence, the two strains appear to be entirely independent of one another.

The symptoms of the disease on either host are swelling and crinkling of the leaves and stems, resulting in extreme cases in marked twisting and bending. Where an abundance of infection is present in the crowns the plants are often killed. In strawberry plants the stolons and the flowering parts are swollen and distorted also.

Several species of Fragaria are capable of becoming infested. The strawberry strain can be transmitted to red-clover seedlings. Attempts to transmit the Hypochaeris strain to other hosts have failed thus far.

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10

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TESTS OF METHODS OF PROTECTING WOODS AGAINST TERMITES OR WHITE ANTS.

A PROGRESS REPORT.

By THOMAS E. SNYDER, *Entomologist, Forest Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

Insects cause very large annual losses of forest products. A conservative estimate of loss, placed at but 2 per cent of the value of the yearly cut of forest products,[1] represents $45,000,000 annually. While much of the loss in both crude and finished forest products can be prevented by proper management, based on a knowledge of the life histories of the insects, nevertheless special preservative treatments are necessary to protect crude manufactured utilized products, such as lumber, dimension timbers (Pl. I, fig. 1), telephone and telegraph poles, mine props, and posts (Pl. I, fig. 6) as well as the more finished products, namely, interior woodwork (Pl. II, fig. 6), furniture (Pl. I, fig. 3; Pl. II, fig. 5), cabinet woods (Pl. II, figs. 1, 2), etc.

Saving forest products will help save our national forests. The various degrees of skilled labor, treatment handling, and change in ownership consequent in the transformation of forest trees into products greatly increases their value. Hence, wood preservation is of vital importance in the national program of forest conservation.

Termites or "white ants" are the insects which are especially destructive to untreated wood in any form, in both this country and the Tropics. Indeed, a large market for both crude and finished

[1] U. S. Dept. of Agriculture, Yearbook 1922, page 172.

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forest products could be found by American manufacturers in South America and in other tropical countries, provided a satisfactory "white-ant-proof" product could be furnished. After a preliminary survey of the extent of the damage throughout the country, a series of experiments were planned, which are outlined herein.

The following pages are a progress report on the results of these experiments conducted at Falls Church, Va., from 1912 to 1922, supplemented by data obtained by inspections of treated timbers made by the writer from 1909 to 1922, in service tests of telephone and telegraph companies. in cooperation with the United States Forest Service.

DESCRIPTION OF EXPERIMENTS.

On August 14, 1912, experiments were begun by the Forest Insect Investigations of the Bureau of Entomology in testing wood preservatives and insecticides to render wood or products of wood resistant to attack by wood-boring insects, especially by termites. Several objects were in view in these experiments.

Tests of the relative effectiveness of preservatives for timber to be set in or in contact with the ground were to be made. Preservatives, to be practicable for such use, should not only be insecticides but also disinfectants or fungicides. They should preferably be of low solubility in water and low volatility so that their poisonous effect will not be quickly destroyed by leaching (in wet situations) or by evaporation. Preservatives with heavy, nonvolatile, insoluble oils as constituents were known to be most effective. These requirements barred many chemicals that are otherwise very effective insecticides.

It was also desirable to determine the relative lengths of periods of effective service that could be expected of the superficial methods of treatment, such as brushing or dipping, compared with the more permanent methods of impregnation. In commercial enterprises, the type of treatment must necessarily be determined by cost and length of service.

When brush treatments are used, only high-grade antiseptic preservatives such as coal-tar creosote oils or carbolineums should be employed, since the cost of application of brush treatments is often high. The cost of any treatment should necessarily be more than offset by the longer service assured by the application. The several methods of application or impregnation of the preservative should be determined by the length of service required and the consequent expenditure warranted.

It was especially important to discover the most suitable preservatives for finished forest products, such as those used in interior finish, furniture, cabinet woods, etc., in order that American manufacturers might compete with foreigners for trade with the Tropics in "white-ant-proof" products. Such preservatives should not stain the wood, should not have a disagreeable odor, and should not "sweat" out in hot climates. It should be possible to paint or varnish over wood treated by them.

The proportions of poisonous chemicals necessary to add in the manufacture of wood-pulp products to prevent attack by termites were to be determined.

Tests were also to be made of untreated native and exotic timbers as to their relative resistance to attack by termites.

In the tests of preservatives for timber to be used in contact with the ground, stakes of southern yellow pine, 2 by 4 inches by 2 feet long, were placed in holes 3 feet apart and 1 foot deep, the holes being dug with a spade, 1 foot of the stake remaining above ground. The treatment of the stakes was done by the Forest Service at the Forest Products Laboratory, Madison, Wis., and a detailed physical description of each stake also was made. (Table 1.)

TABLE 1.—*Treatment and description of stakes treated for the Bureau of Entomology by the Forest Products Laboratory of the Forest Service, Madison, Wis.*

[Length of stake, 24 inches; length treated, about 17 inches.]

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Open-tank, coal-tar creosote (shipment No. 154):		*Pounds.*	*Pounds.*	*Lbs.*			*Inches.*	
Stake 1	Shortleaf.	4.40	4.86	0.46	7	Sound	2.10×3.96	None.
2	...do	3.95	4.57	.62	8	...do	2.06×3.95	None.
3	...do	4.13	5.35	1.22	10	...do	1.94×4.06	None.
4	...do	4.20	4.51	.31	5	...do	1.94×4.08	None.
5	Longleaf.	4.70	6.29	1.59	15	...do	2.12×4.18	2.5
6	Shortleaf.	4.18	4.54	.36	5	...do	1.99×3.97	None.
7	Longleaf.	4.69	5.74	1.05	17	...do	2.15×4.15	.2
8	Shortleaf.	4.63	5.15	.52	7	...do	2.08×4.15	None.
9	Longleaf.	4.71	6.25	1.54	15	...do	2.15×4.18	1.6
10	Shortleaf.	4.19	4.77	.58	10	...do	2.08×3.82	None.
11	...do	4.21	4.58	.37	5	...do	1.92×4.15	None.
12	...do	3.90	4.17	.27	9	...do	1.86×3.96	1
Open-tank, wood creosote (shipment No. 126):								
Stake 13	...do	4.86	5.17	.31	7	...do	1.98×4.15	None.
14	...do	3.35	3.69	.34	7	...do	1.83×3.76	None.
15	...do	3.65	3.88	.23	11	...do	1.98×3.87	None.
16	...do	3.79	4.00	.21	5	...do	2.02×4.00	None.
17	...do	4.23	4.48	.25	5	3 knots	2.04×4.00	None.
18	...do	3.57	3.85	.28	7	1 knot	1.90×3.80	None.
19	...do	3.98	4.29	.31	8	Slight trace of decay.	2.08×4.06	None.
20	...do	5.71	7.32	1.61	13	Small knot.	2.26×4.17	None.
21	Longleaf.	3.65	3.87	.22	7	Sound	2.09×3.93	None.
22	Shortleaf.	3.95	4.37	.42	5	2 knots	2.15×4.13	None.
23	...do	3.37	3.67	.30	5	Sound	1.92×3.78	None.
24	...do	3.58	3.94	.36	5	...do	1.90×3.82	None.
Charred:								
Stake 25	...do	3.87	4.08	.21	8	1 knot	2.17×4.30	None.
26	...do	3.53	3.67	.14	8	Sound	2.14×3.78	.4
27	...do	3.64	3.84	.20	6	...do	2.10×3.31	None.
28	Longleaf.	5.13	5.31	.18	18	Checked	2.21×4.25	None.
29	Shortleaf.	3.27	3.47	.20	5	1 knot	1.94×3.63	None.
30	Longleaf.	4.47	4.72	.25	19	Sound	2.00×4.02	.9
31	Shortleaf.	3.81	3.98	.17	6	...do	2.06×3.80	None.
32	...do	3.29	3.46	.17	7	Large knot.	1.94×3.92	None.
33	...do	4.56	4.81	.25	7	Sound	2.08×4.16	None.
34	...do	3.52	3.69	.17	7	Large knot.	2.06×4.04	None.
35	...do	3.70	3.85	.15	5	Sound	2.00×3.85	None.
36	Longleaf.	5.58	5.93	.35	18	...do	2.25×4.25	None.
Dipping, coal-tar creosote (shipment No. 154):								
Stake 37	Shortleaf.	4.43	4.49	.06	6	...do	2.06×4.01	None.
38	...do	3.33	3.40	.07	5	...do	2.11×3.90	None.
39	Longleaf.	5.75	5.96	.21	15	...do	2.42×4.11	1.3
40	Shortleaf.	3.73	3.78	.05	6	Small knot.	2.15×3.77	None.
41	Longleaf.	5.45	5.60	.15	13	Sound	2.20×4.18	3.8
42	...do	4.61	4.68	.07	12	...do	2.08×3.75	None.
43	Shortleaf.	3.83	3.88	.05	5	...do	2.20×3.90	None.
44	...do	4.21	4.27	.06	6	...do	1.99×3.80	None.
45	...do	4.14	4.21	.07	7	...do	2.15×4.25	None.
46	...do	3.77	3.82	.05	6	...do	1.98×4.02	None.
47	...do	3.66	3.73	.07	7	...do	1.98×4.05	None.
48	Longleaf.	5.15	5.35	.20	16	...do	2.20×4.17	None.

TABLE 1.—*Treatment and description of stakes, etc.*—Continued.

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Brush treatment, 3 coats coal-tar creosote (shipment No. 154):		*Pounds.*	*Pounds.* *I II III*	*Lbs.*			*Inches.*	
Stake 49	Longleaf.	4.10	4.16 4.17 4.17	0 07	12	1 knot	1.95×3.90	None.
50	...do	5.99	6.03 6.04 6.04	.05	16	Sound	2.17×4.20	None.
51	...do	4.49	4.56 4.57 4.58	.09	12	...do	2.06×3.82	1
52	Shortleaf.	3.93	3.98 3.99 4.00	.07	5	2 knots	2.20×4.16	None.
53	...do	3.79	3.84 3.84 3.84	.05	7	Sound	2.05×3.90	None.
54	...do	4.31	4.37 4.38 4.39	.08	6	2 knots	2.08×4.00	None.
55	...do	3.37	3.44 3.45 3.46	.09	5	Sound	1.98×4.00	None.
56	...do	3.99	4.02 4.02 4.02	.03	7	...do	1.95×4.10	None.
57	...do	3.56	3.61 3.61 3.60	.04	7	...do	1.90×3.95	None.
58	...do	3.62	3.68 3.69 3.69	.07	6	1 knot	2.00×3.85	None.
59	Longleaf.	3.94	4.01 4.03 4.04	.10	15	Sound	2.10×3.80	0.4
60	Shortleaf.	3.49	3.55 3.56 3.56	.07	6	...do	1.94×3.82	.5
Dipping, wood creosote (shipment No. 126):								
Stake 61	Longleaf.	5.22	5.33	.11	17	Checked	2.16×4.25	None.
62	...do	4.37	4.46	.09	8	Sound	2.08×3.90	None.
63	...do	5.13	5.35	.22	9	...do	2.10×4.18	3.2
64	Shortleaf.	4.27	4.36	.09	7	...do	2.00×4.10	None.
65	...do	4.23	4.31	.08	6	1 knot	2.12×3.98	None.
66	Longleaf.	5.16	5.23	.07	16	Sound	2.02×4.10	None.
67	...do	4.01	4.10	.09	11	1 knot	1.98×3.90	.4
68	...do	6.03	6.11	.08	16	Sound	2.25×4.18	None.
69	...do	5.23	5.36	.13	16	Slight check	2.23×4.25	None.
70 [1]	Shortleaf.	3.86	3.94	.08	5	Sound	2.00×3.90	None.
71	...do	4.21	4.28	.07	7	1 knot	2.00×4.17	None.
72	Longleaf.	4.08	4.16	.08	8	Sound	2.00×4.00	None.
Brush, wood creosote (shipment No. 126), three coats:			*I II III*					
Stake 73	...do	5.49	5.58 5.60 5.61	.12	13	...do	2.08×4.20	2
74	...do	5.68	5.79 5.82 5.84	.16	13	2 small knots.	2.23×4.15	2
75	Shortleaf.	3.71	3.78 3.79 3.80	.09	6	Sound	1.93×4.10	None.
76	Longleaf.	5.88	5.98 6.00 6.02	.14	13	...do	2.40×4.12	.5
77	Shortleaf.	3.93	3.99 4.00 4.00	.07	5	Large knot.	2.00×3.92	None.
78	Longleaf.	4.63	4.71 4.74 4.75	.12	11	Sound	2.08×4.05	.2
79	...do	4.16	4.24 [2] 4.27 4.26	.10	7	...do	2.10×4.08	None.
80	Shortleaf.	4.63	4.70 4.72 4.73	.10	6	...do	2.11×4.18	1
81	Longleaf.	6.16	6.26 6.29 6.31	.15	11	Large knot.	2.35×4.23	.3
82	...do	5.11	5.20 5.22 5.23	.12	18	Sound	2.10×4.10	.6
83	...do	4.05	4.11 4.13 4.13	.08	8	2 small knots.	1.95×4.09	None.
84	Shortleaf.	3.72	3.78 3.80 3.80	.08	5	...do	2.05×4.13	None.
Brush, carbolineum, three coats:								
Stake 85	...do	4.47	4.53 4.54 4.54	.07	7	Sound	2.00×4.53	None.
86	...do	4.39	4.47 4.50 4.50	.11	7	...do	1.96×4.23	None.
87	...do	4.26	4.34 4.35 4.36	.10	7	Small knot.	1.95×4.23	None.
88	...do	3.95	4.01 4.03 [2] 4.02	.07	4	Sound	1.95×3.85	None.
89	...do	4.46	4.52 [2] 4.53 4.52	.06	7	...do	2.00×4.52	None.
90	...do	3.53	3.59 3.60 3.60	.07	7	...do	2.00×4.10	None.
91	...do	3.54	3.63 3.63 3.63	.09	8	...do	2.07×4.15	None.
92	...do	3.86	3.93 [2] 3.95 3.94	.08	4	...do	1.99×3.87	None.
93	...do	4.27	4.35 4.37 4.37	.10	6	...do	2.02×4.20	None.
94	...do	4.44	4.52 4.55 4.55	.11	6	...do	2.00×4.20	None.
95	...do	3.96	4.03 [2] 4.05 4.04	.08	6	...do	2.10×4.20	None.
96	...do	4.40	4.44 [2] 4.47 4.46	.06	5	...do	2.00×3.85	None.

[1] Attacked by termites.
[2] The apparent discrepancies in Table 1 between the weights of the specimens before and after brush treatments with creosote and similar oils are very likely due to loss of moisture from the wood during the time which elapsed between coats of preservatives. It is quite possible that the wood was brought into the laboratory from outdoors in order to apply the treatments. The laboratory conditions were probably drier than outdoor conditions and the tendency of the wood to lose moisture would be rather marked. It would be quite possible for the wood to lose an amount of moisture greater than the weight of creosote applied in any one brushing.

TABLE 1.—*Treatment and description of stakes, etc.*—Continued.

Treatment and stake No.	Species of pine.	Weight before treatment.	Weight after treatment.	Absorption.	Number of annual rings per inch.	Condition.	Dimensions of cross section.	Square inches of sapwood.
Dipping, carbolineum:		*Pounds.*	*Pounds.*	*Lbs.*			*Inches.*	
Stake 97	Shortleaf.	3.57	3.64	0.07	7	Sound	1.97×4.25	None.
98	...do	4.22	4.28	.06	9	1 knot	1.94×4.20	None.
99	...do	4.10	4.18	.08	6	Sound	2.08×4.27	None.
100	...do	3.84	3.91	.07	7	...do	2.07×4.23	None.
101	...do	4.04	4.12	.08	5	...do	2.00×4.12	None.
102	...do	3.93	3.99	.06	4	Large knot.	1.98×3.73	None.
103	...do	3.79	3.87	.08	7	Sound	2.04×4.00	None.
104	...do	3.64	3.73	.09	4	...do	2.07×3.90	None.
105	...do	3.39	3.45	.06	5	...do	1.90×3.75	None.
106	...do	3.47	3.56	.09	5	...do	2.06×3.88	None.
107	...do	4.07	4.18	.11	6	Large knot.	1.95×3.93	None.
108	...do	3.43	3.53	.10	4	...do	2.00×3.75	None.

Stakes 1 to 12, inclusive, were treated by the open-tank process with coal-tar creosote, Laboratory Shipment No. 154. The preservative was first heated to from 212° to 220° F., whereupon the specimens were immersed, the charge being held at the foregoing temperature for 1½ hours. The charge was then allowed to cool, after which the specimens were removed and weighed. This process was repeated, the specimens being finally allowed to stand in the preservative overnight. The average absorption at the completion of the treatment was approximately 8 pounds per cubic foot.

Stakes 13 to 24, inclusive, were treated by the open-tank process with wood creosote obtained from a turpentine company, Laboratory Shipment No. 126. The specimens were immersed in the preservative at a temperature of 180° F. for 1½ hours, after which the charge was permitted to cool overnight.

Stakes 25 to 36, inclusive, were charred by permitting them to burn for approximately five minutes in an open fire.

Stakes 37 to 48, inclusive, were merely dipped in coal-tar creosote, Laboratory Shipment No. 154, at a temperature of 216° F.

Stakes 49 to 60, inclusive, were brush-treated with coal-tar creosote, Laboratory Shipment No. 154. The temperature of the preservative was 216° F., and three coats were applied at intervals of 24 hours.

Stakes 61 to 72, inclusive, were merely dipped in wood creosote secured from a turpentine company, Laboratory Shipment No. 126, at a temperature of 180° F.

Stakes 73 to 84, inclusive, were brush-treated with wood creosote from a turpentine company, Laboratory Shipment No. 126, three coats being given at a temperature of 180° F. at intervals of 24 hours.

Stakes 85 to 96, inclusive, were brush-treated with a high-grade carbolineum, three coats of the preservative being applied at a temperature of 170° F. at intervals of 24 hours.

Stakes 97 to 108, inclusive, were merely dipped in a high-grade carbolineum at a temperature of 170° F.

Thus 108 stakes were treated in all, numbered from 1 to 108.

One hundred and eight untreated check stakes were also set in the ground with these treated stakes, 54 entirely of heartwood (numbered from 194 to 247), the others with some sapwood; stakes treated by each method or chemical were so arranged that there was an even distribution of treatments throughout the test area. (See fig. 1 for arrangement of stakes; also Pl. I, fig. 5.)

In October, 1916, it was necessary, on account of change in location of laboratory, to move all the treated woods to a new plot near by.

The locality in Virginia where these stakes were set is one in which termite colonies of several species of Reticulitermes were abundant, *R. flavipes* Kol. being the most common termite. No attempt was made to hasten normal attack by termites, hence the

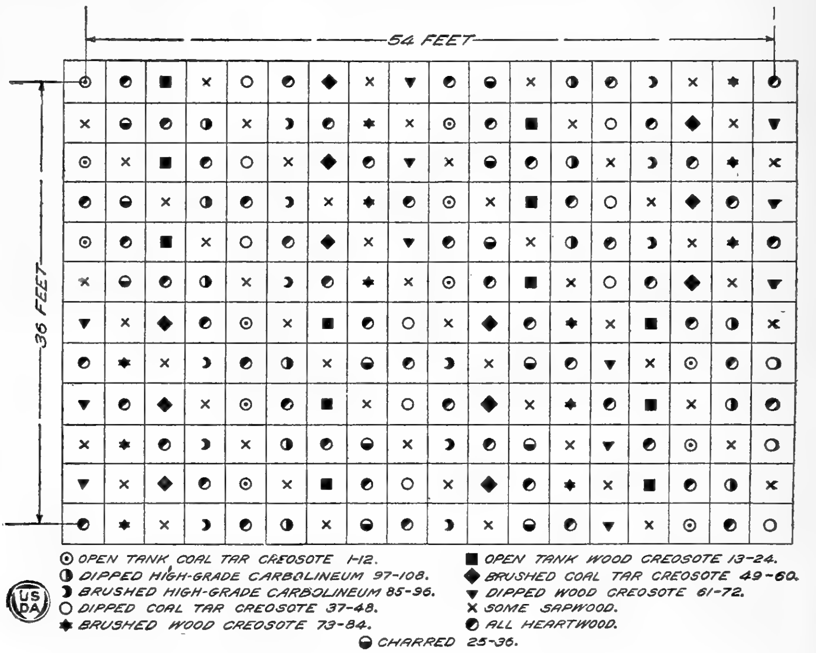

FIG. 1.—Arrangement of experimental stakes at Falls Church, Va.

test is essentially a service test. Some of the untreated stakes had become infested by March, 1913; after one year 57 and after 25 months 95 of the first lot of untreated stakes were attacked by termites.

On May 21, 1913, additional 2 by 4 inch southern yellow-pine stakes were set in the ground, which were treated by more permanent methods of impregnation by a commercial wood-preserving company, using coal-tar creosote oils and wood creosote. Analyses of these coal-tar creosote oils were made by the manufacturer, whereas the wood creosote was analyzed by the United States Bureau of Chemistry, with the results shown in Table 2.

In addition to being attacked by termites both untreated check and treated stakes were also attacked by wood-boring beetles, espe-

cially Eucnemidae,[2] as well as fungi. The tips of many treated stakes were badly checked at the last examination in 1922.

TABLE 2.—*Chemical analyses of oils B or No. 1*[1] *and A or No. 2*[2] *made by the manufacturer.*

	1, B.	2, A.
Standard distillation (totals by weight):		
170°	0	0
200°	0.3	1.1
210°	8.0	8.1
235°	39.2	46.7
315°	42.6	32.5
355°	9.2	6.4
Specific gravity at 15.5°	1.047	1.044
Tar acids ... per cent	8	23
Dry naphthalene ... do	30.08	25.00

[1] Fraction 210°–235° C. solid at laboratory temperature.
[2] All fractions liquid excepting 315°–355° (which contained anthracene).

NOTE.—Dry naphthalene represents solid matter at 15° C., but if cooled to zero sufficient solid matter would be obtained to bring it at least to 40 per cent. The percentage of solids in oil can be increased by lowering the temperature, and a 40 per cent naphthalene oil had been desired in the case of No. 1.

Oil No. 1 (B) was intended for an oil high in naphthalene with a normal tar-acid content, whereas oil No. 2 (A) was intended for an oil high in tar acids with normal naphthalene content.

Pine-tar oil; i. e., wood creosote (Misc. Div. No. 15787):

Appearance, Dark brown, slightly viscous liquid.

Odor, Pine-tarry and empyreumatic.

Specific gravity 29° C	1.0285.
Pyridines	Traces only.
Water and pyroligneous acid	Traces only.
Mineral oils	None.
Ash	0.4 per cent by weight.
Volatile oils excluding phenolic bodies (turpentine, pine oil, and apparently traces of rosin spirit)	12.8 per cent by weight.
Phenolic bodies (guaiacol, etc., volatile tar acids from wood tar, creosote, essentially free from coal-tar acids)	11.9 per cent by weight.
Bodies not distilling below 360° C. (pitch, very heavy oils, etc.)	10 per cent approximately.
Rosin oil and other heavy pine-tar oils (by diff.)	64.9 per cent
Behavior on distillation:	
100° C. to 155° C	1.5 per cent by volume.
155° C. to 180° C	4 per cent by volume.
180° C. to 210° C	16 per cent by volume.
210° C. to 230° C	11 per cent by volume.
230° C. to 270° C	16.5 per cent by volume.
270° C. to 360° C	42 per cent by volume.
Pitch, loss, etc. (by diff.)	9 per cent by volume.

Consists essentially of the so-called heavy oil obtained in pine-tar distillation.

Twelve stakes were impregnated by the full-cell pressure process with creosote oil (Oil B or No. 1, see analysis, Table 2, p. 7) containing a high percentage of naphthalene; 12 stakes were impregnated with a creosote oil (Oil A or No. 2, see analysis, Table 2, p. 7) containing a high percentage of tar acids; 12 stakes were impregnated with wood creosote (see analysis, Table 2, p. 7, No. 15787); 12 stakes were impregnated by the Rueping (empty-cell) pressure process with creosote Oil A or No. 2; 12 were impregnated with creosote Oil B or No. 1, and 12 impregnated with wood creosote. There were 72 treated stakes in all. In addition, 12 stakes were treated to refusal

[2] Especially *Dromaeolus striatus* Lec.

with Oil A, No. 2. Stakes under these treatments were numbered from 109 to 193, and received the treatments shown in Table 3.

TABLE 3.—*Oils and processes used in impregnating Stakes 109 to 193.*

Oil A.		Oil B.		Wood creosote.		Oil A.
Full-cell.	Rueping.	Full-cell.	Rueping.	Full-cell.	Rueping.	Special.
Stake.	*Stake.*	*Stake.*	*Stake.*	*Stake.*	*Stake.*	*Stake.*
117	168	112	115	110	134	109
118	169	113	119	131	150	114
121	171	126	120	132	151	122
123	172	127	124	133	152	148
125	173	128	116	147	156	174
144	177	130	138	153	157	175
149	178	135	139	155	158	181
176	179	136	140	167	159	183
182	180	137	142	170	160	186
187	184	143	146	190	162	189
188	185	145	161	192	163	----------
111	191	166	164	193	165	----------

Treatment marked "Special" treated with oil to refusal.

Stakes 129, 141, and 154 were missing.

With these treated stakes were placed 22 untreated check stakes. (See fig. 2 for arrangement of stakes.)

Other treated stakes have since been added to this test at irregular intervals.

Coal-tar creosote oils containing varying percentages (high and low) of naphthalene and tar acids were included in the test treatments, since it was formerly considered that a high percentage of naphthalene in coal-tar creosote oils was more effective against marine borers and that a high percentage of tar acids was more effective as an antiseptic in preventing fungous decay.

Some of the objections to coal-tar creosote as a wood preservative are discoloration, odor, and smarting to eyes and touch, "sweating" in hot climates, soiling clothes, and corroding rubber insulation; that is, when conduits are impregnated with creosote, the creosote is said to be injurious to the rubber insulation on cables. Wood treated with creosote can not be painted or finished after treatment.

Many of the objections can be avoided by proper treatment and regulating the amount of creosote held in the wood by the "empty-cell" or "open-tank" impregnation treatments. Impregnation with coal-tar creosote is by far the most effective treatment for timber to be placed in or in contact with the ground. Attack by termites to a telephone pole line in Virginia is very slight (usually through season checks), after 25 years' service. By adding pigment to creosote, as is done in the preservative treatment given shingles, a painted effect can be obtained which does away with the brown discoloration,

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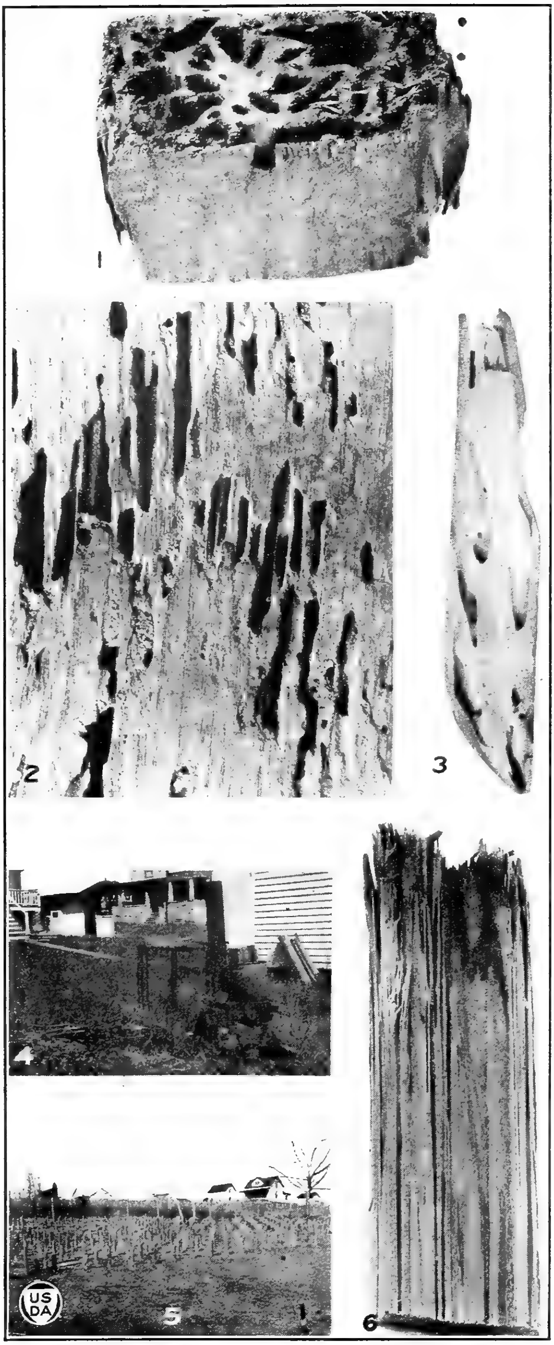
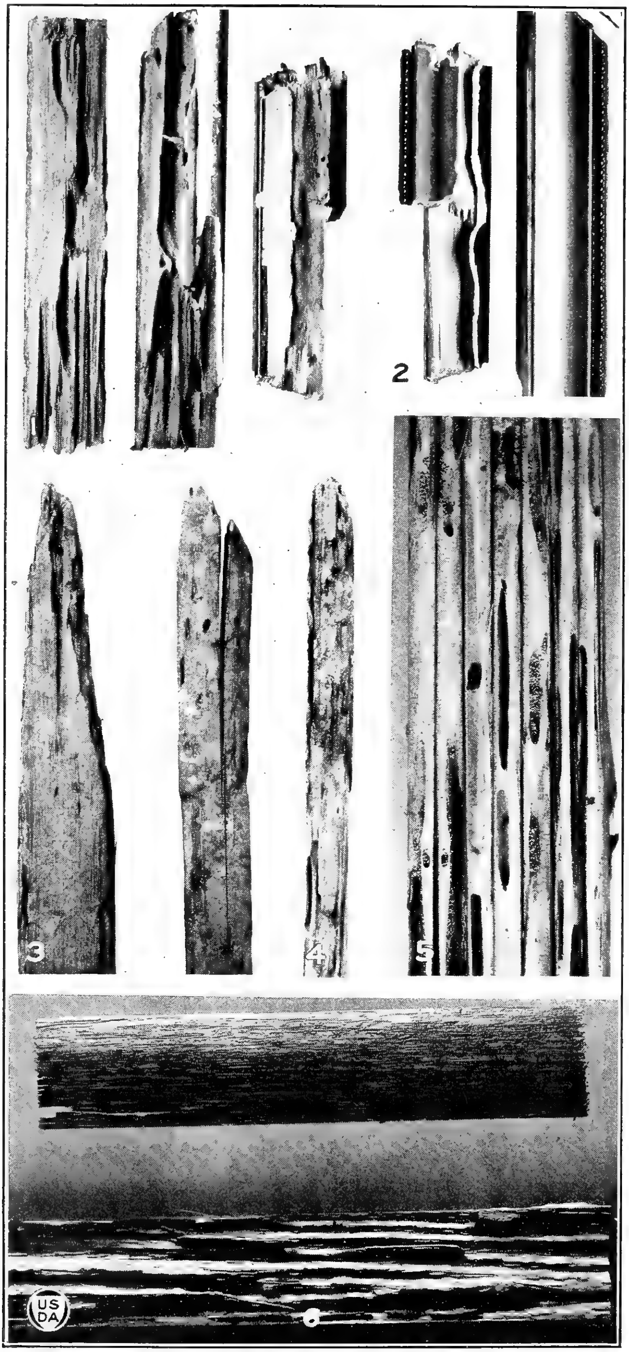
DESCRIPTION OF PLATE I.

EXPERIMENTAL WORK WITH WOOD PRESERVATIVES AND DAMAGE TO RESISTANT REDWOOD AND WOODWORK IN BUILDINGS BY TERMITES: 1, Section of woodwork in building damaged by *Cryptotermes brevis* at San Jose, Costa Rica. 2, An ineffective method of wood treatment. Experimental ash block steamed 10 hours at 28 pounds pressure, after 6 months' tests buried in the ground with logs infested by Reticulitermes in Virginia. 3, Rocker of rocking chair damaged by *C. brevis,* Key West, Fla. 4, Homemade, crude "open tank" plant at eastern field station, Falls Church, Va. 5, View of a portion of the treated experimental stakes at Falls Church, Va., March, 1917. 6, One of several fence posts of redwood (*Sequoia sempervirens*) (heartwood) damaged by the termite *Reticulitermes humilis* var. *hoferi* from Sabino Canyon, Santa Catalina Mountains, Ariz.



WOOD DAMAGED BY TERMITES AND EXPERIMENTAL WORK WITH WOOD PRESERVATIVES.



RESISTANT REDWOOD DAMAGED BY NATIVE TERMITES, AND OTHER DAMAGE TO WOOD BY TERMITES.

and the substance apparently dries more quickly. Tests have proved that the addition of pigments, notably green, does not affect the resistant qualities of the treated wood.

The quantity of pigment (green) added to the creosote oils used in the experiments was 1 pound of pigment to 1 gallon of creosote. It is believed that satisfactory physical properties can be obtained by reducing the amount of pigment, if the pleasing stain is not of primary importance. The wood which was treated was yellow pine and was more than half seasoned. Where the mixture was applied by means of dipping, coal-tar creosote and pigment alone were used; but where creosote and pigment were applied with a brush the mixture was slightly thinned with linseed oil, so as to encourage drying and make the application easier.

According to the Forest Products Laboratory, red and brown pigments are less expensive than green; furthermore, a smaller amount of red or brown pigment is necessary to obtain a satisfactorily colored creosote than in the case of green. Red and brown pigments can be used by the open-tank method or pressure method, whereas

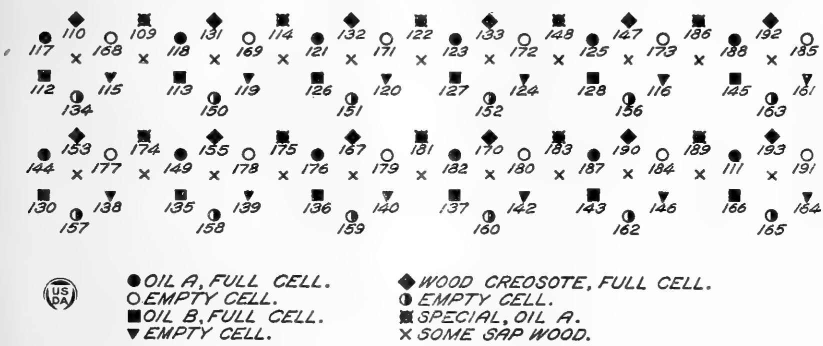


FIG. 2.—Arrangement of stakes treated by the cylinder pressure process at Falls Church, Va.

brushing or dipping must be used with green. The proportions are 8 to 12 ounces of pigment (ground in oil) mixed with an equal bulk of linseed oil for each gallon of creosote.

TREATMENTS FOR TIMBER TO BE SET IN THE GROUND.

SUPERFICIAL TREATMENTS.

The superficial brushing and dipping methods are temporarily effective in preventing attack by insects to timber and crude forest products; results of tests and examinations of service test telephone pole lines indicate that the treated wood set in the ground usually resists attack by wood-boring insects from 2 to 8 years, depending upon the chemical, the thoroughness of the treatment, the character

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DESCRIPTION OF PLATE II.

RESISTANT REDWOOD DAMAGED BY NATIVE TERMITES AND OTHER DAMAGE TO WOOD BY TERMITES: 1, Picture molding infested and ruined by *Cryptotermes brevis* in the old Colonial Hotel, Nassau, N. P., Bahamas, 1921. View showing damage exposed. 2, Same, showing how interior is eaten out, leaving hollow shell but with outer layers intact. 3, Permanent redwood stakes to support grapevines in Merced County, Calif., vineyards damaged by the termite *Reticulitermes hesperus*, which also injures the young vines. Side view. 4, Same, edge view. 5, Bureau drawer injured by the termite *C. brevis*, Key West, Fla. 6, Oak flooring damaged by Reticulitermes in the eastern United States; note how damage is hidden (upper surface).

of the site, and the geographical situation. Coal-tar creosote and carbolineums have been found to be the most effective preservatives. Several coats of coal-tar creosote brushed on timber will add from 2 to 5 years to its life. In the tests at Falls Church, Va., brushing with coal-tar creosote (three coats applied hot) was more effective in preventing attack by termites than was dipping in the hot preservative. As has been stated, much depends upon the preservative.

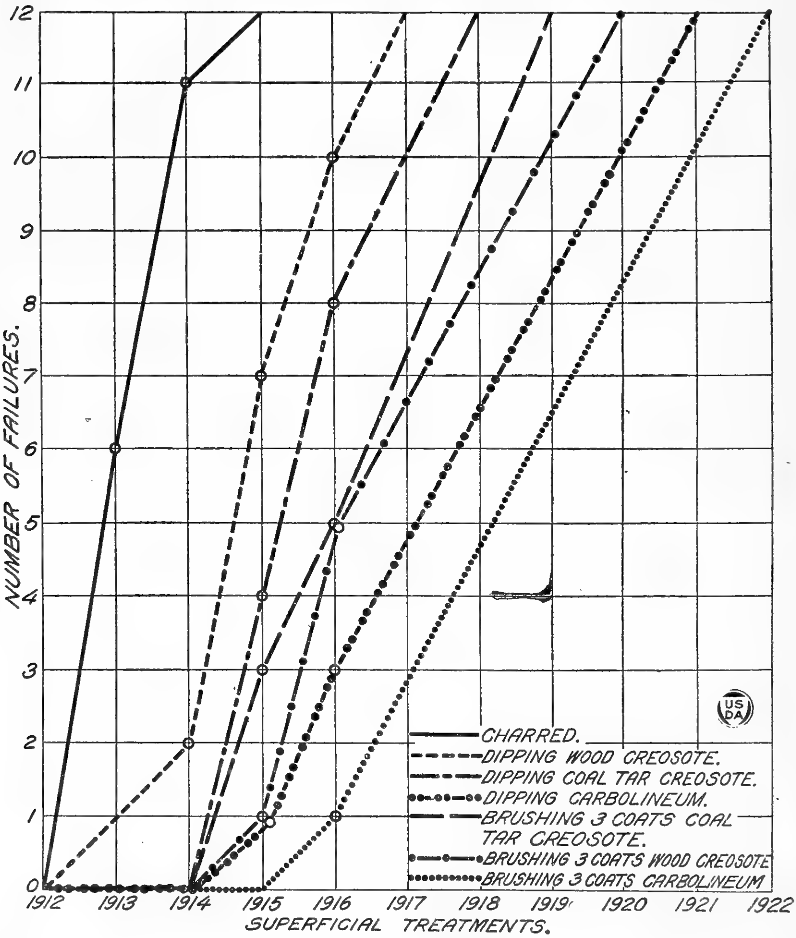

FIG. 3.—Comparison of the relative resistance to attack by termites of chemical wood preservatives and methods of treatment, Falls Church, Va., 1912–1922.

Heavy or thick coatings of tar for the bases of poles or posts are not effective and are valueless as preservative treatments. Many patented or proprietary preservatives or methods failed after short periods of test and are not referred to, except in a few cases.

IMPREGNATION TREATMENTS.

Methods by which the preservative is more thoroughly impregnated into the wood more permanently protect wood from insect attack. These methods of course are more expensive. Inspections of

treated timber by the writer indicate that the "open-tank" method of impregnation with coal-tar creosote renders wood resistant to attack by wood-boring insects for at least 15 years. Treating of wood by this method can be done with homemade apparatus (Pl. I, fig. 4), using unskilled labor. The timber should be well seasoned before impregnation, however, and the treating should be very carefully done; a uniform penetration should be secured, sufficiently deep to allow for season checking; this is especially necessary if the treated timber is to be set in warm climates.

Impregnation treatments by the more technical pressure processes are the most effective, as well as the most costly, but the results usually justify the extra cost. Inspections of treated timber by the writer indicate that impregnation by the full-cell pressure process will render wood resistant for at least 25 years.

The results of the tests of the comparative effectiveness of the superficial methods of treating timber in protecting it against attack by termites are given in Figure 3 and Table 4, while the results of the impregnation treatments are given in Table 5.

TABLE 4.—*Results of tests of the relative effectiveness in preventing attack by termites of miscellaneous superficial chemical preservative treatments for crude or finished forest products.*

Preservative.	Method of application.	Species of wood treated.	Effectiveness.
Liquid M, a volatile yellow fluid, 2 per cent solution.	Both brushing, 2 coats applied hot, and dipping.	Yellow pine	Failure after 4 months.
"Ebonizing," chromic acid and aniline oil.	Brushing, applied hot.	Ash and yellow pine.	Failure after 5 months.
Liquid S, a yellowish oily liquid with a strong varnish odor.	Both brushing, 2 coats (one week between coats), and dipping.	Yellow pine	Failure after 6 months.
Preservative T, a preservative paint	Both brushing and soaking.	Ash	Failure after 1 year.[1]
Oil S, a creosote oil made from coniferous wood.	Brushing	Chestnut	Effective for less than 5 years.[1]
Oil C, a very light gravity brown oil, containing much tar, acids, and water.	do	do	Do.[1]

[1] Period when first examination was made after setting.

TABLE 5.—*Results of tests of methods of impregnating woods with preservatives to prevent attack by termites, 1913 to 1922.*

Treatment.	Results.
Full-cell pressure process:	
Commercial wood creosote (No. 126), tested with yellow pine	No failures.
Commercial coal-tar creosote (No. 154), tested with yellow pine	Do.
Coal-tar creosote oil A, tested with yellow pine	Do.
Coal-tar creosote oil B, tested with yellow pine	Do.
Steaming for various periods under different pressures, tested with ash	Failure after 6 months.[1]
Empty-cell pressure process, using yellow pine for test:	
Commercial wood creosote (No. 126)	5 failures out of 12 in 1922.
Commercial coal-tar creosote (No. 154)	No failures.
Coal-tar creosote oil A	Do.
Coal-tar creosote oil B	Do.
Open-tank process, using yellow pine for test:	
Commercial wood creosote (No. 126)	1 failure in 1916; 5 failures out of 12 in 1922.
Commercial coal-tar creosote (No. 154)	No failures.
Coal-tar creosote oil A	Do.
Coal-tar creosote oil B	Do.
Boiled in iron sulphate solution for 2 hours, then plunged in copper sulphate solution and left for 2 hours.	Failure after 5 years.

[1] Period when first examined after placed in test.

TABLE 5.—*Results of tests of methods of impregnating woods, etc.*—Continued.

Treatment.	Results.
Open-tank process, using yellow pine for test—Continued.	
Boiled 1½ hours in a stock solution of poisoned kerosene emulsion (1 gallon water, 2 gallons kerosene oil, ½ pound naphtha soap, ½ pound sodium arsenate)—	
Allowed to cool in mixture	Failure after 6 years.
Cooled and dipped in carbolineum	Do.
Boiled 1 hour in 2 gallons of creosote emulsion poisoned with ½ pound sodium arsenate—	
Allowed to cool in the mixture	Do.
Left in kerosene oil for 1 hour after treatment	Do.
Left in coal-tar creosote for 1 hour after treatment	Do.
Boiled 1 hour in 1 gallon kerosene oil, 1 gallon coal-tar creosote, ½ pound naphtha soap, ½ pound sodium arsenate, 1 gallon water; allowed to stand 1 hour in carbolineum.	Not attacked by termites after 6 years' test.
Boiled ½ hour in a 5 per cent solution of sodium arsenate and left soaking for 2 days, then boiled for 1 hour in sodium arsenate and soaked for 1 hour in carbolineum.	Do.
Boiling:	
Paraffin wax, tested with both coniferous and hardwood species	Failure after 6 months.
Saccharine solution and arsenic, tested with maple and ash	Failure after 1½ years.
Chlorinated naphthalene, tested with both coniferous and hardwood species	Not attacked after 3 years.
Impregnation and baking:	
Formaldehyde and carbolic acid combination, tested with pine	Failure after 8 years.
Encysting:	
Naphthalene, paraffin, and silica, tested with ash	Failure after 7 years (sweat badly).

OTHER TREATMENTS.

There are also simpler though less effective methods other than treatment with chemicals to prolong the life of timber, such as setting in stone, charring, steaming (Pl. I, fig. 2), etc. By burning (i. e., for poles, posts, etc.) in an open fire till the outer layers are charred, wood is rendered more resistant to insect attack. Charred wood will not be damaged by termites till one year after being set in the ground, and not seriously damaged till after at least two years of service. However, charring should not be depended upon to preserve wood, although it is quite possible that it renders the wood more resistant to insect attack. A more effective method is to dip the butts of fence posts for a few minutes in crude oil and then char them.

TREATMENTS FOR WOOD PRODUCTS NOT TO BE SET IN CONTACT WITH THE GROUND OR IN WET SITUATIONS.

Finishing products—such as cabinet woods, furniture, and the interior woodwork in buildings—as well as unfinished products stored to season before finishing, require treatment different from that given to crude products to be set in the ground. While the preservatives with which such woods are to be treated should generally be antiseptic, they should never be insoluble in water, except in the case of flooring or other woods near or in contact with the ground. These preservatives in most cases should not "sweat out" or stain the wood. Impregnation with 2 to 5 per cent solutions of zinc chlorid by the Bethel full-cell process or "Burnettizing" is in most common practice; only the woods which treat with the greatest difficulty require 6 per cent solutions.

Timber impregnated with sodium fluorid is apparently as resistant to attack by termites as timber impregnated with zinc chlorid (standard specification one-half pound of dry salt per cubic foot). Sodium fluorid, however, is much more expensive than zinc chlorid.

Another method is the "Kyanizing" process, consisting of a steeping treatment with a 1 per cent solution of bichlorid of mercury; this chemical, however, is extremely poisonous (see p. 15), which may greatly restrict its use. All of the above treatments are effective for flooring, interior woodwork, other fixtures, or furniture.

Impregnation with chlorinated naphthalene is an effective treatment for valuable cabinet woods or expensive furniture; it is also a moisture-retarding treatment.

Chlorinated naphthalene is a crystalline wax with a melting point of about 196° F. It is made in several grades varying in specific gravity, melting point, and other characteristics, according to the extent to which the chlorination process is carried.

The chlorinated naphthalene used in these tests is a mixture of various chlorinations as well as free naphthalene, with a large preponderance, however, of tri chlor naphthalene.

This material is usually referred to as tri chlor naphthalene and, as compared with other chemicals, it is really comparable to a technical product having naphthalene, mono chloro naphthalene, di chlor naphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F. This is the specification under which it is sold.

The grade used in these tests, as identified by the melting point stated, sells at 36 cents per pound in carload lots; a less refined grade can be purchased for 20 cents per pound in the same quantity.

The samples of wood for test were treated as follows: Blocks of the wood 6 by 6 inches by ½ inch were placed, without previous drying, in an open pot of the chlorinated naphthalene at a temperature of from 220° to 240° F. and allowed to remain fully covered by the molten wax for 15 minutes. The blocks of wood were then removed and wiped off with a cloth. The treated wood can be stained, shellacked, and varnished. The resultant color will be somewhat darker than the color of untreated wood, and care must be exercised in cleaning the surface thoroughly to insure proper adherence of shellac or varnish.

The different woods varied greatly in the amount of wax taken up in the above treatment. Furthermore, the amount of wax taken up will vary according to the size and condition of the wood treated. The blocks carried approximately 5 per cent of wax, or at the rate of from 2 to 3 ounces of wax per board foot. At the above price for the impregnating material, the treatment would be rather expensive and possibly prohibitive for ordinary use, such as flooring.

The treatment also renders the wood moisture-retarding to a marked degree, and its cost is sometimes justified by this double effect.

In the tests of untreated woods and woods that were treated with preservatives for use in finished forest products, such as furniture, cabinets, etc., experimental blocks of wood from various species of both coniferous and broad-leaved trees were buried in the ground with logs heavily infested with termites (*Reticulitermes* spp.) at Falls Church, Va. These blocks were 6 inches square by one-half

inch thick. These experiments were begun on April 10, 1913. The blocks were examined twice each year. Similar test blocks were sent to the Tropics (Brazil, Ecuador, and Cuba) for test under more severe conditions.

In the experiments untreated woods and certain treated woods failed after 6 months' exposure to the attacks of termites. This is a very severe test for finished forest products, since in use they would not be placed in the ground.

After a three-year test, it was found that tropical woods, such as teak, mahogany, and peroba, while resistant to termite attack, are not wholly immune; they stand in the order named in comparative immunity.

The woods from the northeastern part of the United States, untreated, are very susceptible to attack. Treatment with paraffin accomplished nothing, as the woods were readily attacked and also suffered decay. Treated with chlorinated naphthalene, the woods from the Northeastern States were attacked but little, comparing favorably with untreated teak and mahogany. (Table 5.)

Many preservative treatments for furniture and cabinet woods are objectionable, since they discolor or will not permit fine finishes. In these cases the hidden, interior parts may be so treated and then be covered by veneers of cabinet woods which are resistant to attack by termites.

TERMITE-RESISTANT WOODS.

The results of tests conducted from 1913 to 1922 at Falls Church, Va., and inspections in the field by the writer, appear to warrant the statement that there is no species of tree the wood of which is absolutely immune to attack by termites. Nevertheless, the heartwood of certain trees is very resistant to attack by termites (*Reticulitermes* sp.).

Among the most resistant woods which were tested are teak (*Tectona grandis*) and sâl (*Shorea robusta*) of India; cypress-pine (*Callitris robusta*) and camphor wood (*Cinnamomum camphora*) of the Orient; greenheart (*Nectandra rodiaei*) of South America; redwood (*Sequoia sempervirens*) (Pl. II, figs. 3, 4); western red cedar or giant arborvitae (*Thuja plicata*);[2] incense cedar (*Libocedrus decurrens*); Port Orford cedar (*Chamaecyparis lawsoniana*); yellow cypress (*Chamaecyparis nootkatensis*), and species of Junipers (*Juniperus* spp.) of the United States.

Certain other South American and Philippine woods were tested on too small a scale to warrent definite statements as to their relative resistance to attack by termites. Many of these woods may prove to be very resistant. Further tests should be made.

It is the presence of certain chemical constituents of the wood which renders it resistant. Stakes of longleaf pine (*Pinus palustris*) of Texas, cut from butt logs containing a large resin content (locally called "fatwood" or "lightwood") remained unattacked by termites after being set in the ground exposed to their attacks from 1913 to 1922, whereas normal pine wood is very susceptible to attack by termites.

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[2] Red cedar poles are seriously damaged by termites (Kalotermes) in California.

Certain of the woods named would make very suitable veneers to overlay and conceal chemically treated interior and hidden parts of furniture, which could be made of any of the cheaper woods of the United States. Impregnating with zinc chlorid or steeping with bichlorid of mercury would be a suitable treatment of the cores or interiors, after which the resistant woods could be glued upon them. *The extremely poisonous character of mercuric chlorid renders its use dangerous. It is slowly volatile and there is a possibility that it will be given off continuously in small quantities from the treated wood. This matter should be carefully considered in case mercuric chlorid treatment is used for furniture and other household articles made from Kyanized wood. Coatings with heavy white lead paint might prove a safeguard.*

POISONS FOR WOOD-PULP PRODUCTS.

In the tests of insecticides for wood-pulp products, white arsenic, sodium arsenate, bichlorid of mercury, zinc chlorid, phenol (carbolic acid), copper sulphate, antimony, sodium fluorid, and creosotes were tested. The wood-pulp products in the test were various processed boards used in interior finish and as substitutes for lath, tiling, etc.

Where the board was made of four plies of fiber laminated with silicate of soda, some samples were treated on each ply before lamination, while others were treated only on the surface. These tests were made in the Tropics in cooperation with American manufacturers. For the money invested, crude carbolic acid and creosotes gave the best results, though the odor is a disadvantage. A summary of the results is given in Table 6.

Canvas finished by the cupra-ammonium process is not attacked by termites. This process consists in subjecting the fabric to the action of a solution of copper hydroxid in ammonia, whereby a compound of copper and cellulose is formed on the surface in addition to some change in the physical character of the fabric due to partial solution and reprecipitation of the cellulose. The treatment is readily removed by acids and other solvents for copper oxid and fades gradually on exposure to the weather. It has never been determined in the Bureau of Chemistry whether this fading is due to actual loss of copper or whether it is due to chemical change.

TABLE 6.—*Results of tests of wood-pulp products treated with poison to prevent attack by termites.*

Treatment.	Amount per square foot.	Amount per 1,000 square feet.	Cost per 1,000 square feet.	Condition of sample after attack of white ants.
	Ounces.			
Untreated	None.	None.		Badly attacked; eaten through to silicate.
Zinc chlorid in plies		111 pounds.. 22½ pounds..	$1.01	Badly attacked but not eaten through to silicate.
Zinc chlorid on surface		7 pounds	.31	Very slightly attacked.
		3 pounds	.14	Slightly attacked.
Crude carbolic acid		10 gallons	3.50	Unattacked.
		6 gallons	2.10	
		1 gallon	.35	Do.
Painted 2 coats both sides				Slightly attacked.

TABLE 6.—*Results of tests of wood-pulp products, etc.*—Continued.

Treatment.	Amount per square foot.	Amount per 1,000 square feet.	Cost per 1,000 square feet.	Condition of sample after attack of white ants.
	Ounces.			
Bichloride of mercury on surface.	0.054	1.01 pounds	$1.77	
	.043	.82 pound	1.42	Very slightly attacked.
	.043	.41 pound	.72	
	.049	.46 pound	.80	Unattacked.
	.040	.076 pound	.13	Very badly attacked; eaten through the silicate layers on both sides.
	.045	.034 pound	.15	
Copper sulphate on surface	.051	6.4 pounds	.35	Do.
	.045	5.2 pounds	.29	
	.113	14.1 pounds	.77	Unattacked.
	.082	10.5 pounds	.58	
Turpentine	1.25	12.1 gallons	5.06	Badly attacked; eaten through to silicate in small places on both sides.
	1.25	do	5.06	
Turpentine and varnish on surface.	1.51			
	1.93			
Paraffin dipped at 132° F		71.0 pounds	2.49	
Paraffin dipped at 150° F		62.5 pounds	2.28	Very slightly attacked.

Results not given in some cases.

SUMMARY.

The most effective preservative in protecting timber to be set in the ground from attack by termites is coal-tar creosote. The length of service required must determine whether the method is to be a superficial treatment or a more costly but permanent impregnation.

Impregnation by the "open-tank" method with coal-tar creosote renders wood resistant to attack by termites for at least 15 years. Impregnation by the full-cell process with coal-tar creosote renders wood resistant for at least 25 years. This method is recommended for wood to be exported for use in tropical countries.

Brushing several coats of coal-tar creosote on timber will add from 2 to 5 years to its life; pigments may be added to the oil to give the wood a painted appearance.

For interior woodwork, furniture, cabinet woods, etc., impregnation with zinc chlorid, bichlorid of mercury, sodium fluorid, or chlorinated naphthalene is effective; the woods can be painted after such treatments.

Another protective method is to treat the hidden, cheaper cores of furniture, cabinet woods, etc., with preservatives during manufacture and then overlay them with veneers of termite-resistant woods.

Effective poisons to be added to wood-pulp products during manufacture are crude carbolic acid and coal-tar creosote.

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DAMAGE BY TERMITES IN THE CANAL ZONE AND PANAMA AND HOW TO PREVENT IT.

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CONTENTS.

INTRODUCTION.

In a preliminary paper Dietz and Snyder (*2*)[2] have given an historical survey of the status of the termites of Panama and have written of their habits and ravages to both living vegetation and the woodwork of buildings as well as to other works of man. This bulletin gives additional original data on the habits of the termites of this region, the damage they do, and their control. In the case of some of the species recently described by Snyder (*8*, *9*) there has been no knowledge of their habits—and they are very injurious—since they had been confused with other known termites. Special attention has been given to damage by termites to lead-sheathed cables in conduits in locks of the Panama Canal and at other localities in Panama, as well as damage to telephone and lighting equip-

[1] The field notes were made by Mr. Zetek and the specimens were collected by him and by Ignacio Molino. All the determinations were made by Doctor Snyder, who has also helped to interpret the field notes and has prepared the manuscript.
[2] Reference is made by number (italic) to "Literature cited," p. 25.

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ment. Such damage has been caused by *Leucotermes tenuis* Hagen, *Coptotermes niger* Snyder, and *Nasutitermes ephratae* Holmgren.

There is also a discussion of the possibility of termites acting as mechanical carriers of the nematode *Aphelenchus cocophilus* Cobb, which causes "red-ring" disease of coconut palms. Although species of Nasutitermes, Eutermes, and Coptotermes infest the trunks of coconut palms or have runways on them, only *Coptotermes niger* Snyder has been found with these nemas on the bodies of the workers.

As in the Dietz-Snyder paper (*2*), all specimens were given numbers in the field. All field observations and photographs of nests, galleries, damage, etc., are supported by numbered specimens of the termites. This insures accuracy and avoids confusion; it affords a check in case of wrong determinations, for the notes can then be identified easily and properly placed.

GEOGRAPHICAL DISTRIBUTION.

Apparently more species of termites inhabit the Pacific slope than the Atlantic slope of the Canal Zone. On the Atlantic slope the rainfall is greater. Mr. Zetek states that at Colon, in 1913, there were 246 rainy days, whereas at Ancon there were only 180, and the total precipitation was 131.22 inches and 65.98 inches, respectively; he has prepared a table (Table 2) giving the rainfall for 1921 for the 13 towns, with comments. This is particularly interesting, especially since many termites are so dependent upon moisture.

Reference to a map of Panama (Pls. I and II)[3] will show the Rio Chagres flowing practically southwestward, and receiving tributaries from both the north and south sides. Along the Atlantic side are rivers that empty into the Caribbean Sea and along the Pacific coast are rivers that enter the Gulf of Panama. There are, then, two more or less parallel divides, the first skirting the Atlantic coast, the second skirting the Pacific coast. Most people seem to have the erroneous idea that there is but one divide.

The Hydrographic Office, Bureau of Navigation, Department of the Navy, considers the central section as from Culebra (more or less near Pedro Miguel) to Monte Lirio. This is based on the original divisions made by the chairman of the Isthmian Canal Commission when the canal was being built. The central region is not considered by the present writers to extend beyond Darien.

Zetek has thus divided the Canal Zone into three regions—the Atlantic (as far as Darien), the central (from Darien to Pedro Miguel), and the Pacific (from Pedro Miguel to Panama). The great Gatun Lake has, of course, greatly altered this arrangement, and it may be necessary to change these limits somewhat. The central zone is a sort of transition zone, now less evident than when the digging of the canal was begun. The flooding of Gatun Lake killed the trees, and the insects had to go elsewhere and adapt themselves to new surroundings, or else die out. They emigrated in great numbers, no doubt, and a large proportion did well in their new abodes after some fighting with those already in possession.

[3] The map shown in Plate II is adapted from Plate I in Mammals of Panama, by E. A. Goldman (Smithsonian Miscel. Col., vol. 69, no. 5, 1920).

At first it was believed that a dense jungle bordering the canal would be ample protection against a foe. Later, a United States military officer found that his men could go through a dense jungle rapidly and with precision and without making much noise. It was then decided to clear away the jungle and have pastures and plantations in its place. The jungle was therefore cut down, allowed to dry, and then burned over. This radically destroyed insect habitats and killed off immense numbers of insects. Those that escaped had to go elsewhere; and as the plantations were started, many species found these good habitats and became more destructive to crops and to structures of man.

Much more collecting will have to be done before it is possible to do much generalizing on the distribution of termites in the Republic of Panama. The interior region should yield interesting termites. The termite mound nests described by Dudley and Beaumont have never been refound.

Table 1 gives the distribution of only those specimens of termites which were the basis for this bulletin.

TABLE 1.—*Geographical distribution of termites in the Canal Zone and Panama.*[1]

Family and species.	Locality.	Atlantic slope.	Pacific slope.	Both slopes.
Kalotermitidae:				
Kalotermes tabogae Snyder	Taboga Island, Republic of Panama.		X	
Cryptotermes thompsonae Snyder	Ancon, Canal Zone		X	
Rhinotermitidae:				
Leucotermes tenuis Hagen	Ancon, Canal Zone		X	
	Chitre, Republic of Panama		X	
	Miraflores, Canal Zone		X	
	Panama City, Republic of Panama.		X	
	Venado Plantation, Canal Zone		X	
Coptotermes niger Snyder	Ancon, Canal Zone		X	
	Cristobal, Canal Zone	X		
	Frijoles, Canal Zone	X		
	Miraflores, Canal Zone		X	X
	Panama City, Republic of Panama.		X	
	Pedro Miguel, Canal Zone		X	
	Summit, Canal Zone		X	
Termitidae:				
Nasutitermes cornigera Motschulsky.	Ancon, Canal Zone		X	
	Chitre, Republic of Panama		X	
	Frijoles, Canal Zone	X		
	Miraflores, Canal Zone		X	X
	Panama City, Republic of Panama.		X	
	Taboga Island, Republic of Panama.		X	
	Venado Plantation, Canal Zone		X	
Nasutitermes ephratae Holmgren	Ancon, Canal Zone		X	
	Matias Hernandez, Republic of Panama.		X	
	Miraflores, Canal Zone		X	
Nasutitermes columbicus Holmgren.	Frijoles, Canal Zone	X		
Subulitermes zeteki Snyder	Summit, Canal Zone		X	
Anoplotermes gracilis Snyder	Alhajuela, Panama[2] (Upper Chagres River Basin).		(2)	
Eutermes debilis Heer	Ancon, Canal Zone		X	
	Taboga Island, Republic of Panama.		X	

[1] This table gives only the distribution of the specimens of termites which were the basis for this bulletin.
[2] Central interior

TABLE 2.—*Rainfall in the Canal Zone and Panama in 1921.*

Month.	Pacific section.				Central section.					Atlantic section.			
	Taboga Island.	Balboa.	Miraflores.	Pedro Miguel.	Culebra.	Empire.	Gamboa.	Juan Mina.	Frijoles.	Monte Lirio.	Gatun.	Colon.	Porto Bello.
1921.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
January	1.53	1.49	0.26	0.04	0.03	0.15	0.09	0.23	2.50	3.32	2.01	1.31	4.21
February	.65	3.14	.76	1.53	.84	1.58	5.39	1.05	4.19	2.93	2.74	1.63	5.20
March	.58	3.29	1.46	.17	.36	.52	.09	.03	1.07	.26	.79	.98	2.57
April	.92	1.90	1.91	1.17	.42	.65	1.16	2.38	4.87	6.63	4.69	7.43	6.61
May	8.05	8.28	7.78	8.72	6.12	7.28	5.89	4.43	10.73	9.76	14.08	13.61	17.46
June	4.87	7.20	7.67	9.81	9.51	9.36	12.81	11.87	16.49	15.23	13.23	15.18	18.77
July	4.32	8.92	7.08	7.02	11.02	11.72	11.33	16.05	16.74	15.50	13.17	10.49	13.59
August	8.25	9.38	9.94	9.41	12.57	13.90	15.68	19.80	15.70	15.41	19.73	18.45	30.32
September	5.32	3.28	5.27	7.26	9.94	7.85	10.48	13.52	13.94	15.69	13.71	11.21	10.65
October	11.25	14.76	14.30	11.06	10.58	13.65	11.83	18.42	9.79	9.28	9.09	8.27	4.84
November	3.45	5.20	5.09	8.78	11.99	10.47	6.96	8.85	19.37	22.26	21.04	19.96	31.34
December	4.28	4.81	4.13	3.42	4.86	4.39	4.42	3.88	7.19	8.87	9.03	6.50	9.53
Total	53.47	71.65	65.65	68.39	78.24	81.52	86.13	100.51	122.58	125.14	123.31	115.02	155.09
Station average	51.75	67.95	78.59	79.32	86.84	80.90	90.79	95.03	101.77	118.85	120.00	127.85	160.00
Number of years of record	7	23	13	14	31	17	39	11	10	14	17	51	10
Number of rainy days	103	173	163	190	176	224	227	?	?	248	267	252	308

Rainfall for the year was slightly above normal over the Pacific coast and the greater part of Gatun Lake, and slightly below over the Atlantic coast and southern part of the central section. January and March were the months of least rainfall. August and November were generally months of greatest rainfall. The 1921 dry season was not very dry, as has been the case during some past years.

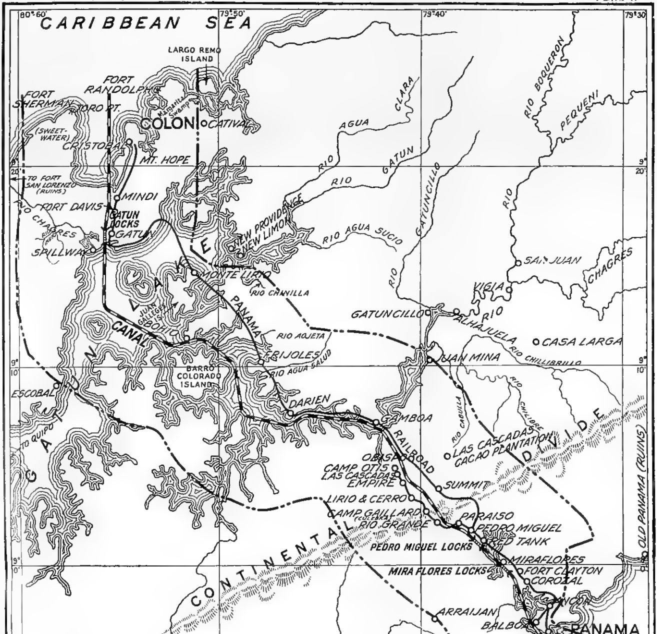
RELATIVE DAMAGE BY THE FAMILIES OF TERMITES.

Species in the family Rhinotermitidæ are apparently the most injurious termites in Panama, although very destructive species occur in the families Kalotermitidæ and Termitidæ. Damage by species in the family Rhinotermitidæ include injury to living trees, the woodwork of buildings and other timber, and damage to lead-sheathed cables. Species in the family Kalotermitidæ are very injurious to the dry woodwork of buildings and furniture in buildings, whereas species in the family Termitidæ are injurious to living fruit, coconut, and other trees, the woodwork of buildings, fence posts, and telephone and lighting equipment.

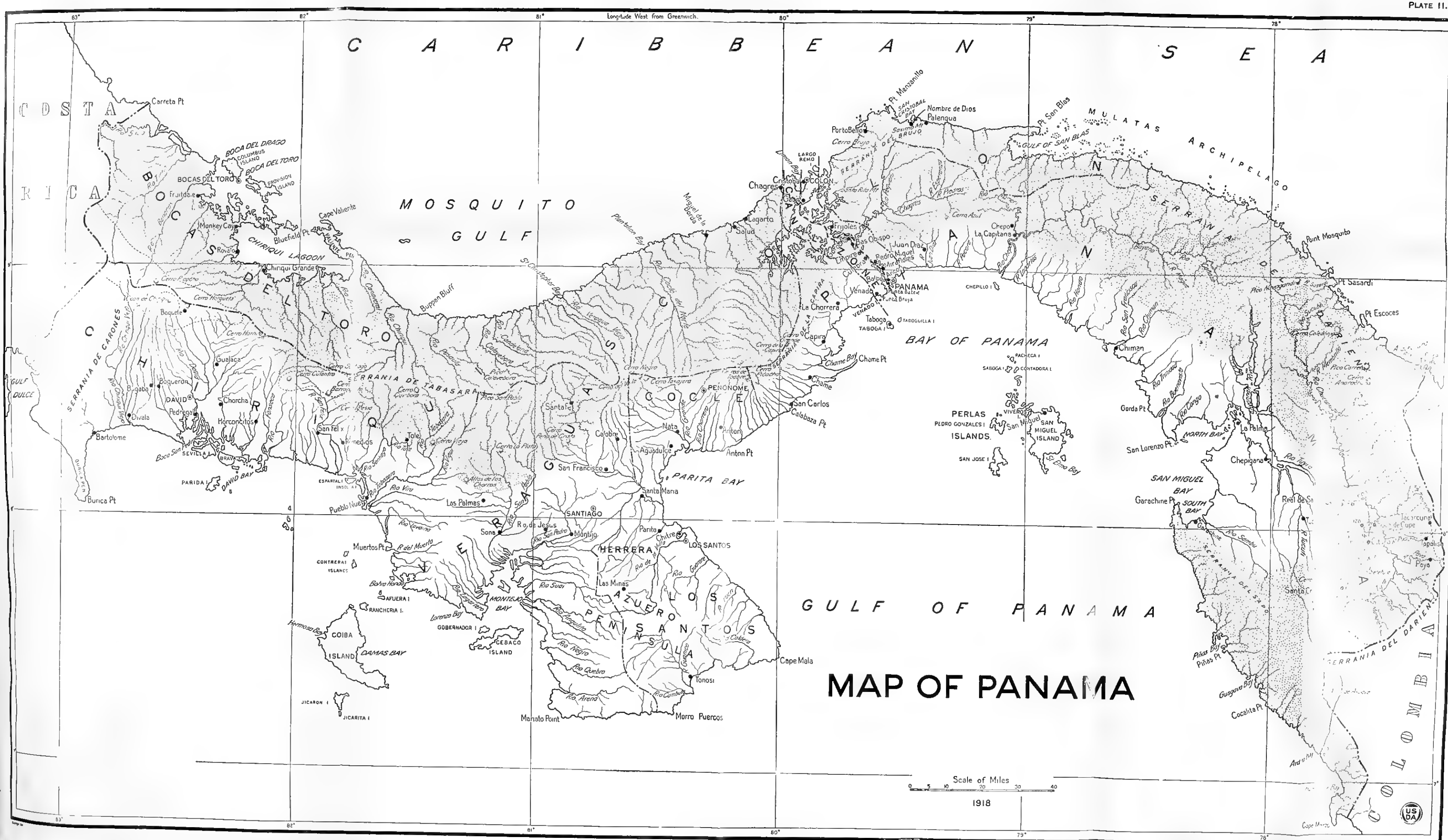
Damage by termites is serious on both the Atlantic and Pacific slopes.

Sometimes, particularly in case of furniture in buildings, it is difficult to determine what species of termite is responsible for the damage without destroying the infested article. This is due to the fact that soldiers or winged or deälated adults have to be found in order to identify the insect. In other cases, when the owner finds furniture or books damaged by termites his wrath is so great that he destroys the articles without saving specimens of the termites. This was the fate of a volume of La Salle law books destroyed by termites on a shelf in a building in Panama City (Pl. X, *C*).

Aside from the damage done by termites to the woodwork of buildings and their contents, the flight of the winged termites is a great annoyance in Panama. When these termites swarm or fly in great numbers, as has been noted at several localities in Panama, notably



Map of the Panama Canal and Canal Zone, Showing Location in the Republic of Panama.



MAP OF PANAMA. DOTTED AREAS INDICATE HUMID DIVISION OF LOWER TROPICAL ZONE. (ADAPTED FROM GOLDMAN.)

at Las Sabanas, which is the "summer" section for the fairly well-to-do Panamans, where they have their cottages and much land, they are a great nuisance. The native Panamans go to Las Sabanas after the carnivals if these are held early in the year, i. e., at the commencement of Lent. If the Lenten season begins late, they go as soon as the dry season begins, and for the carnival season return to their city homes. As soon as the rains start, these "palomitas"[4] begin to appear and the people take their presence as a warning to return to the city, as rains are coming fast. Those who heed not this warning find that they must eat early and hurriedly and even then it is a battle with these clumsy insects. The people say these winged termites "drive them crazy," and they certainly make them more nervous and increase their neurasthenia; the hurried eating and constant thought of the pests, fighting them off, or dishing them out of the soup or sancocho, produce marked digestive disturbances.

KALOTERMES TABOGAE Snyder.

Specimens of Kalotermes collected at Panama at first appeared to be identical with *K. marginipennis* Latreille, which occurs in the southwestern United States; nevertheless, it is a new species. *K. tabogae* works in dry woodwork and is destructive. As in the case of species of Cryptotermes, its presence can be recognized by the impressed pellets of excrement expelled from infested wood, as well as by the small round holes in the wood—entrance and exit tunnels. These pellets are called "carcoma" in Spanish, and furniture so destroyed is said to be "carcomido." In the majority of cases the native does not recognize this as termite (comejen) work, but thinks that it is caused by a different insect which he terms "carcoma," and until this fine distinction in terms is learned an argument is the usual result.

Very probably much damage to woodwork credited to this species in the past, before the identity of other and new species was recognized, was caused by other species, especially those of the genus Cryptotermes.

At Taboga Island, Republic of Panama, on March 30, 1922, Zetek collected winged sexual adults of *Kalotermes tabogae* attracted to a lighted kerosene lamp. At that date the dry season was at about its height. The rainfall record (in inches) for 1922 was as follows: January 1, 0.45; 2, 0.35; 3, 0.13; 9, 0.10; 17, 0.07; 23, 0.10; 31, 0.04 (an excess of 0.81 inch over station average). February 8, 0.06; 17, 0.09; 21, 0.10; 22, 0.02; 26, 0.20 (an excess of 0.31 inch over station average). March 21, 0.03 (a deficiency of 0.08 inch over station average). April 7, 0.08; 9, 0.09 (a deficiency of 1.12 inches over station average).

Of course, species of the family Kalotermitidae do not depend so much upon moisture for their existence as do termites of the other families.

At Ancon Hospital grounds, Ancon, Canal Zone, on June 19, 1922, Zetek and Molino collected deälated adults in a dead tree on which there was loose bark perforated with numerous holes of a scolytid beetle. The termites were in burrows identical with those of the

[4] "Palomitas de San Juan" is the full native name for any dark-colored flying termites.

scolytid, but showing additional enlargements. This is the same tree on which workers and soldiers of *Eutermes debilis* Heer were collected on October 26, 1921, from shelter tubes. Workers and a few soldiers of *E. debilis* were again collected on June 19, 1922; soldiers were scarce.

CRYPTOTERMES THOMPSONAE Snyder.

Several species of Cryptotermes occur at Panama, but *C. thompsonae* is the only one on which the writers have any biological notes. It is very destructive to the dry woodwork of buildings.

On July 25, 1921, Zetek and Molino collected soldiers and winged and deälated sexual adults of *Cryptotermes thompsonae* from a poplar case (Pl. III, *D*) in the office of the Board of Health Laboratory at Ancon, Canal Zone. This wooden case is a survival of the equipment of the old wooden hospital and was put into this ward when the new hospital building was completed. The termites were mostly in the baseboard. The winged forms were not very abundant and were congregated in small "pockets;" the soldiers were not aggressive or plentiful.

Zetek found soldiers and deälated sexual adults in hard beech wood of a drawer of a desk in Section B of Ancon Hospital on August 30, 1921. The desk had been in this screened concrete building for five years (Pl. III, *A*).

The dry hardwood of a back panel of an organ in the Roman Catholic Chapel at Ancon, Canal Zone, was found by Zetek, on October 19, 1921, to be damaged by this termite. The insects had gone into nearly all parts of the wood (Pl. III, *B*). No winged forms were present and soldiers were very scarce; nymphs of the sexual adults were abundant. Out of the back of this organ as much as 500 cubic centimeters of impressed pellets of excrement (Pl. III, *C*) could have been obtained; the actual size of these pellets is 0.85 by 0.54 millimeter.

Deälated adults were collected on June 19, 1922, under bark on the trunk of a dead tree on the Ancon Hospital grounds.

LEUCOTERMES TENUIS Hagen.

Species of Leucotermes are very similar in habit to species of Reticulitermes. Nevertheless, unlike the latter, they consistently line their galleries with white excrement (not spotted) and live in association with other insects. Earthlike shelter tubes (Pl. IV, *A*, *B*, *C*) are constructed by species of both genera. Two species of Leucotermes occur in Panama, namely, *tenuis* Hagen and *convexinotatus* Snyder; apparently these species do not greatly differ in their habits; each species occurs on both the Atlantic and Pacific slopes. Species in this genus not only injure living vegetation and the woodwork of buildings, but also damage lead-sheathed underground cables.

On August 10, 1921, Zetek and Molino found a nest on the trunk of a coconut palm on the Venado Plantation, Venado, Pacific slope, Canal Zone. The termitarium was about 8 inches by 5 inches, of earthlike material, soft outside and harder within, and composed largely of cells. This "nest" was partly within the trunk—about 2 inches. It contained workers, soldiers, and a first-form queen

with abdomen greatly distended; this queen measured 22 millimeters in length and 4.5 millimeters in width. The shelter tunnels were small, about one-fourth inch in width.

Leucotermes tenuis was found on November 15, 1921, infesting redwood window sills and frames at Ancon. These sills faced the inner court of the board of health laboratory and supported the 18-mesh wire screens. The termites were on both the first and second floors and in both places were making covered galleries along the concrete side, in a downward direction. In 24 hours they constructed from 8 to 15 inches of these galleries. On the first floor the galleries were in the direction of the drain pipe, and although repeatedly brushed away, were always reconstructed in the same general direction. The screens are always well wetted with a hose every Friday, so as to be clean of dust, etc., and consequently the wooden sills also get wet. The redwood quarter-round was taken out and found to be decayed in places and wet. The sill proper, of 2-inch material, was not flush against the concrete, hence was not very wet, excepting where the small wedges held it in place. The termites were only in the decaying parts of the redwood, not in any sound wood. As a remedy, the affected sections of wood were cleaned of decayed and infested material, then wetted with a strong solution of sodium fluorid, and new quarter-round strips put in, the flat surfaces of which were painted with the sodium fluorid. To date (June 20, 1922) there have been no further signs of the termites. This, of course does not necessarily imply that the sodium fluorid was responsible for repelling them. No termitarium was found anywhere.

At Ancon, Canal Zone, on November 23, 1921, workers and a very few soldiers of this termite were found in an old piece of discarded wood of a stairway. This indicates a habit similar to that of species of Reticulitermes which will infest any wood, sound or decayed, lying on or in contact with the ground for even short periods of time.

On November 29, 1921. Zetek and Molino found workers and soldiers of this termite in Spillway Tunnel, Miraflores, Canal Zone, 70 feet below the surface. These termites were found only in the west end of this long tunnel, and apparently had entered through that end, following the stairway, along the walls. Their galleries along these walls were very numerous (Pl. IV, *A*, *B*, *C*). The top of the tunnel is a flat arch, and at the west end there is a tall vertical shaft leading to the floor of the entrance to the tunnel. Where the ceiling of the flat arch meets the vertical shaft wall it was found that in several places the termite galleries, which followed the surface

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DESCRIPTION OF PLATE IV.

INJURY BY THE TERMITE *Leucotermes tenuis* TO LEAD-COVERED CABLES AT MIRAFLORES LOCKS, C. Z.: *A*, View along concrete wall in tunnel in spillway, 70 feet below surface, showing characteristic galleries. Black circle is hole left after a piece of wood was taken out. This wood was completely tunneled by the termites. Small black spots on concrete are bits of crude oil or paint. November 19, 1921. *B*, *C*, Characteristic views of termite galleries, taken by E. St. Clair Clayton by flashlight, in tunnel below spillway. Galleries were very numerous, standing out in bold relief upon white concrete. In places they were seen to lead to moisture. November, 1921. *D*, *E*, Flashlight views of tunnels of termite *L. tenuis* to show how sometimes shelter tubes project into space, forming branching structures. Workers were seen frequently in openings at ends of these tunnels, building them up further. View taken in long tunnel below spillway at Miraflores, 70 feet below surface. White part is concrete ceiling of tunnel, dark portion is space—a vertical shaft leading to surface 70 feet above. November 19, 1921.

of the ceiling, had been built out into space, forming weird branching effects (Pl. IV, *D*, *E*). The workers were seen at the ends of these free galleries, adding particles to them. The longest of these very unusual and interesting free, branching shelter tubes measured exactly 5 inches from the point of attachment to the free end. Along the concrete walls, where the galleries were scraped off, small holes made by these termites right into the concrete were found in places. These holes were usually at an angle of about 45° to the surface, and in one case almost 1 millimeter in depth, although the majority were only about one-half millimeter deep. In all probability these intrusions into the concrete are made only in soft places, and the writers do not believe that any process of solution, due to the liquid ejected from the mouth or frontal gland opening of the termites, is involved. Additional notes are given in the legends to the photographs (Pl. IV) illustrating this species.

This termite was found also in a manhole opposite lamp post 600, east wall, Miraflores Locks, Canal Zone (lake side) on the same day. They were along the concrete and along the lead-sheathed cables in the manhole.

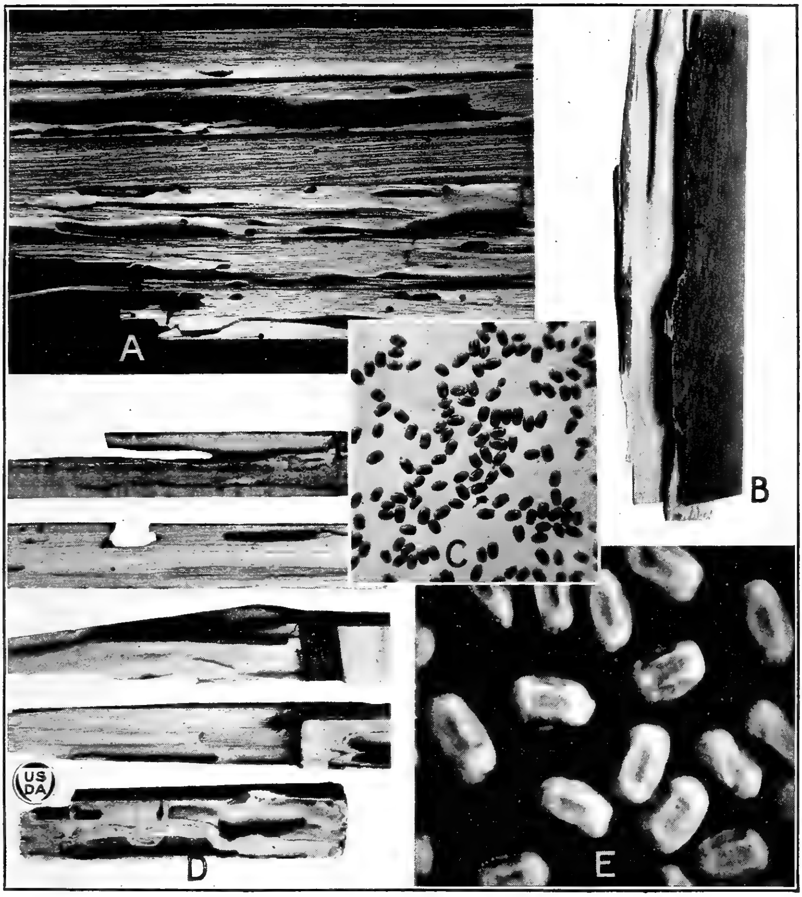
On November 30, 1921, Zetek and Molino found shelter tubes of *Leucotermes tenuis* in the restaurant of Ancon Inn, Panama City, J Street, near to Ancon, Canal Zone. Several good termite galleries were seen starting from the cross timbers of the ceiling and continuing down the walls. In one case the gallery as it left the timber was suspended in the air and was not attached to the wall until a point about 11 inches from the timber was reached; from this point, however, it descended the wall. In another case about 16 inches of shelter tube was free from attachment to the wall. At 10 p. m., November 29, a mark was made at the end of one of the wall galleries. The next day at 10 a. m. this was inspected and it was found that in this 12-hour interval the termites had built 12½ inches of additional gallery. At the opening of the gallery, but protected by the walls of the tube, two soldiers were stationed. The slender workers came out of the tube, sometimes as much as twice the length of their bodies, and with their mouths deposited something resembling flyspecks on the wall surface. From one to three workers came out at the same time and did not appear to be troubled by the light. Other workers were seen to add small pellets to the still fragile end of the built tube. On scraping the gallery, parts of the plaster and concrete were found into which the termites had made impressions, but these were extremely shallow, not over 0.25 millimeter deep.

INJURY TO LIVING CROPS.

On April 25, 1922, Zetek found *Leucotermes tenuis* infesting sugar cane on La Chironga Farm, near Chitre, Republic of Panama. The infested cane is usually brownish in color, and the damage was frequently from 10 to 35 per cent. Thus far this appears to be the most serious sugar-cane pest in Panama.

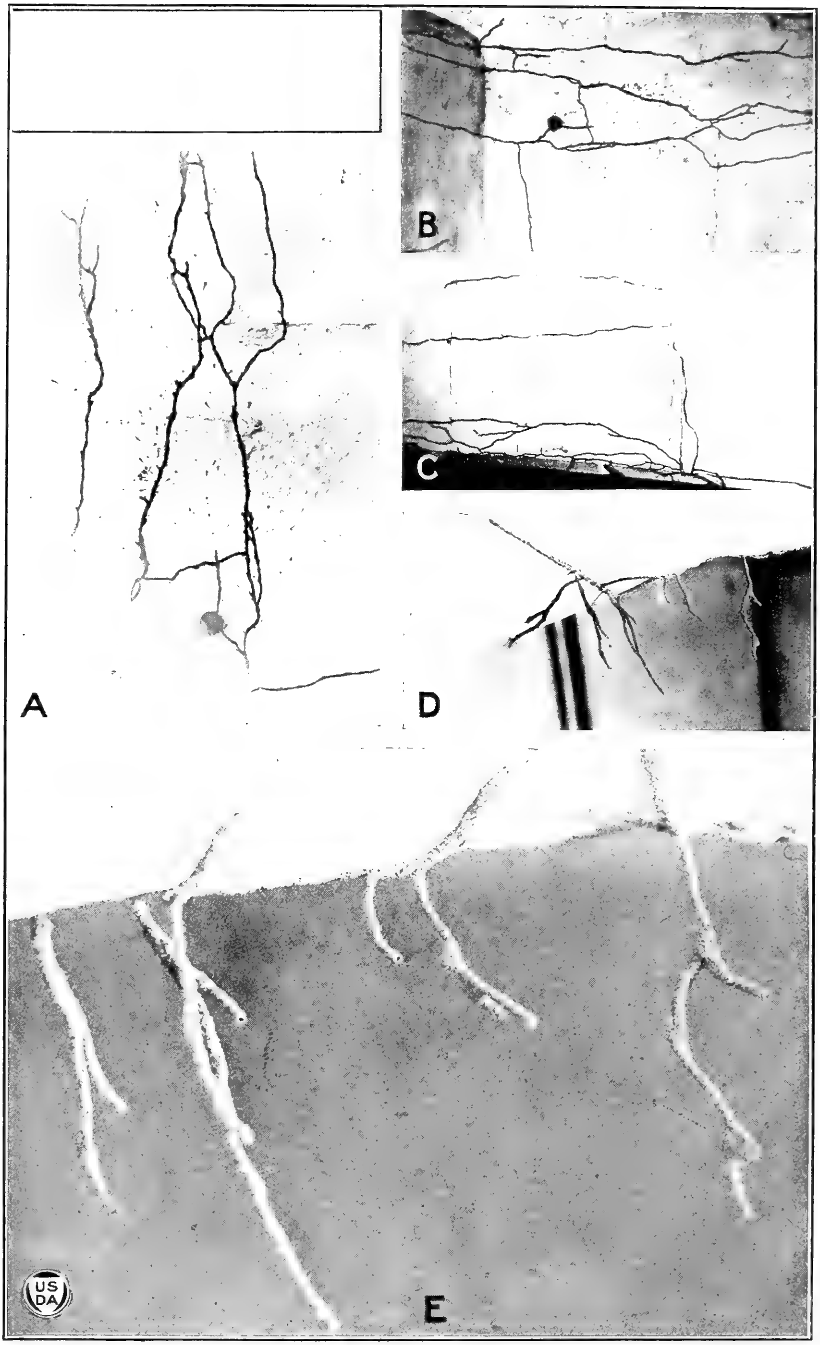
COPTOTERMES NIGER Snyder.

As was predicted, *Coptotermes niger* is proving to be one of the most destructive termites of Panama. These termites injure living



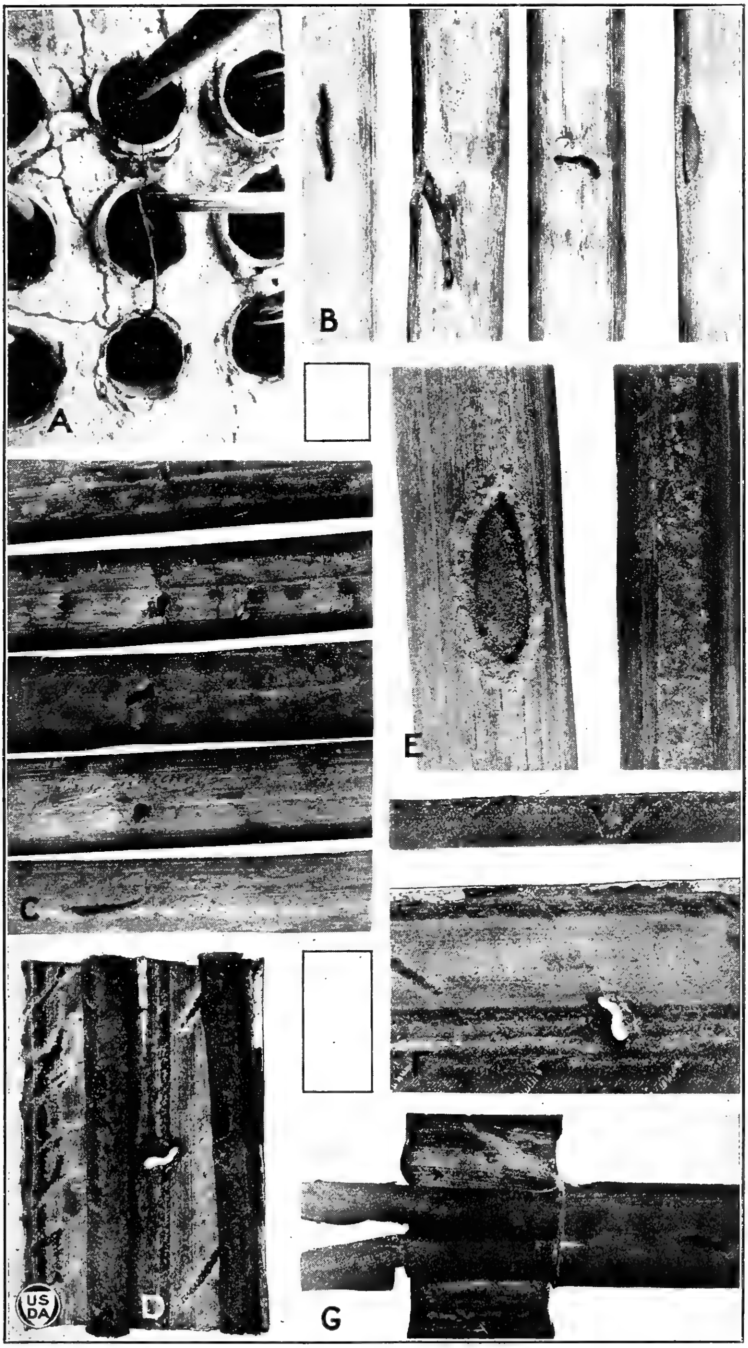
DAMAGE BY KALOTERMITDAEI TO THE DRY HARD WOOD OF FURNITURE IN BUILDINGS.

A, Hard beech wood from a drawer of a desk damaged by *Cryptotermes thompsonae*, in a building at Ancon, C. Z. *B*, Back panel of an organ in a chapel at Ancon, damaged by *C. thompsonæ*. *C*, Pellets of *C. thompsonae* near natural size. *D*, Wood from poplar case damaged by *C. thompsonae* in a building at Ancon, C. Z. *E*, Impressed pellets of excrement of *C. thompsonae*, greatly enlarged; actual size, 0.85 by 0.54 millimeter.



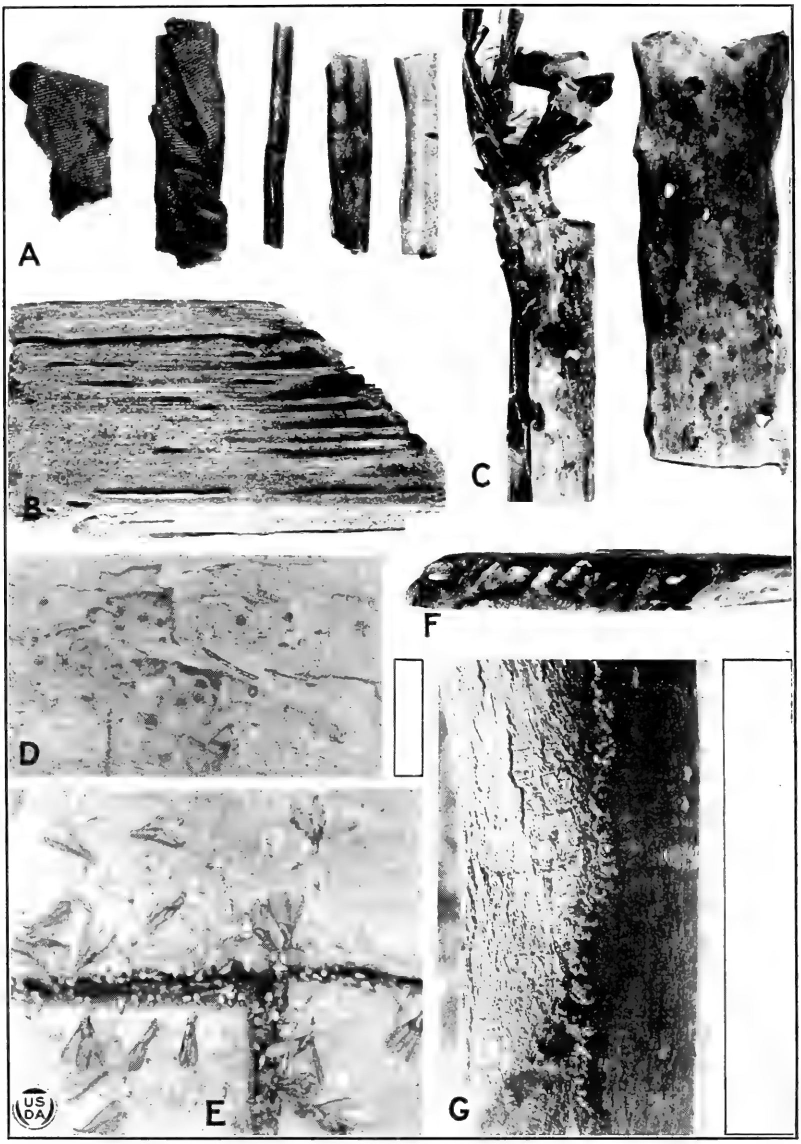
INJURY BY THE TERMITE LEUCOTERMES TENUIS TO LEAD-COVERED CABLES AT MIRAFLORES LOCKS, C. Z.

Description at foot of page 6.



INJURY TO LEAD-COVERED CABLE BY THE TERMITE COPTOTERMES NIGER AT MIRAFLORES LOCKS, C. Z.

Description at foot of page 10.



DAMAGE TO LEAD-COVERED CABLES BY THE TERMITE COPTOTERMES NIGER.

A, Tape, rubber, and paper insulation perforated; near Cristobal. *B*, *F*, Damage to wood form under concrete wall cover to tunnel through which cables run at Miraflores Locks. *C*, Damage to lead cable and insulation on this tunnel. *D*, Galleries of *C. niger* in trunk of coconut palm at Ancon, C. Z. *E*, Swarm of colonizing sexual adults of *C. niger*, showing workers and soldiers; from central wall, central tower, Miraflores Locks. *G*, Shelter tubes of *C. niger* on avocado tree at Frijoles, C. Z.

vegetation, woodwork of structures, and lead-sheathed cables. A white, thick liquid is secreted from the frontal gland opening in the head of the soldiers which serves as an effective material of defense.

On July 26, 1921, Zetek collected soldiers and workers in galleries on the trunk of a black palm at La Loceria, Tumba Muerta Road (near Corundu River), near Panama City. These galleries were made of red earth and were thick, rough looking, flat, baked from the heat, and cracked; the main ones were from 4 to 8 inches wide and about one-half to three-fourths inch thick. From the main galleries smaller ones branched off. The termites were in the wood of the palm tree also. The soldiers when uncovered stood their ground and made lively jerky movements.

On October 26, 1921, Zetek and Molino found soldiers and workers of *Coptotermes niger* on and in the trunk of an unknown tree at Ancon Hospital. The galleries consisted of a main one one-fourth to five-sixteenths inch wide, of earth, firm in texture, beginning at the earth surface and reaching to about 2 feet above, then bifurcating, one branch leading to one "seminest,"[5] the other to another one. These "seminests" were of earth, with galleries, firm, about 2 inches by 4 inches in size, and extending about 1 inch into the wood. Many soldiers but few workers were present in the tunnels and wood. Several small "seminests" of earth, hard and brittle, were found in small hollows in the trunk of a "mamey de tierra" tree (*Lucuma mammosa* Gaertn.), at Ancon Hospital on this same day by Zetek and Molino. These nests were about 2 inches to 3 inches by 1 inch to 2 inches thick, and from them tunnels extended into the wood of the trunk. Scratching the bark of the tree brought out the soldiers.

INJURY TO LEAD-SHEATHED CABLES IN THE LOCKS OF THE PANAMA CANAL.

On November 7, 1921, Zetek and Molino collected specimens of *Coptotermes niger* in the center wall of Miraflores Locks, Canal Zone. The insects had eaten into the lead sheathing of the duplex cables. This damage to the lead was first noted about November 1, when the telephone service was unsatisfactory. R. S. Mills, acting assistant superintendent of the Pacific locks, then in charge of the Miraflores section, and E. St. Clair Clayton, one of the operators in the control house at the Miraflores Locks, are responsible for calling attention to this injury and for helping in every possible way to get data, specimens of the insects and of the damaged cables, and photographs (Pls. V and VI). M. N. Shaw, cable splicer, first found this infestation about three weeks before the date (November 7, 1921) mentioned above. No positive data as to money value of the loss could be obtained. Fifty feet of duplex lead-covered cable had to be replaced and the cost of the cable, the salary and time of the cable splicer, etc., would easily amount to $100.

No. 12 stranded rubber and lead-covered duplex 600-volt cable is used for telephone service; for ringing, 110 volts 25-cycle alternating current is used; for talking, 24-volt battery current is used.

An 8-conductor braided and rubber-insulated lead-covered control cable, carrying 220 volts, 25-cycle, alternating current, was also at-

[5] *Coptotermes niger* does not construct regular external nests as do some termites, but builds earthlike nests in hollows in wood, as well as honeycombing the wood, in a manner similar to that of species of Reticulitermes.

tacked. This cable carried two spare wires (neutrals), not used. This was in the crossover wells, i. e., away below the floor of the lock chamber. In this case the cables have a certain definite twist and the termites followed the two spare, unused wires, and kept entirely away from the wires carrying the high-tension current.

It is the writers' opinion that much more damage was done, but that it was sporadic in nature, so that it was entered in the records only as repair work, of which there is always plenty.

The damage was confined particularly to one small section along the center wall of these locks, between two or three of the light posts. The duplex cable, which measures 9 by 19 millimeters on cross section, runs through conduit pipes that are 3½ inches in diameter (Pl. V, *A*). The particular type of injury is well illustrated in the photographs (Pl. V, *B–G*). As a rule, the termites had their galleries attached to the lead-covered cables. At places, for some reason or other, they worked into the lead, perforated it, and then traveled between the two insulated wires (Pl. V, *D*), there being some space between these wires. As this space is not wide enough, they chewed away the insulating material, including the rubber (Pl. V, *D*, *E*). The hole through the lead is usually enlarged on the inner surface. They travel thus between these two wires for spaces of a foot or so, sometimes only for a few inches, and then emerge again and build the galleries along the outside of the lead cable. It is estimated that there was a hole every foot or so (Pl. V, *B*, *C*, *G*). The particular damage to the service is due to the entrance of moisture through these holes.

In another instance these termites cleaned off on the duplex cable a section about 15 inches in length along the narrow edge, thus giving the cable a flat surface and making it look very much as if it had gone through a shaper machine, excepting that the surface was not very smooth. (Pl. V, E.)

The center wall of the locks consists of a main tunnel near the surface, extending only as far as there are lock gates. Since the center wall is prolonged farther than the two side walls, the outer part has no tunnel, but only manholes, some of these large recesses being big enough for a man to walk around in. Each manhole feeds two lampposts. It was at one of these that most of this damage was noted.

It was found that in these manholes and recesses plenty of moisture was usually present, and in most instances some of the timber was

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DESCRIPTION OF PLATE V.

INJURY TO LEAD-COVERED CABLE BY THE TERMITE *Coptotermes niger* AT MIRAFLORES LOCKS, C. Z.: *A*, View in one of larger manholes, in center wall of locks, showing ends of 3½-inch conduit pipes and duplex lead-covered cable coming out of these. Across second (middle) pipe is seen a termite gallery which started in the pipe above and is completely separated from the wall. Below middle pipe is seen continuation of it, about one-half inch suspended. Wandering galleries along concrete wall coalesce in places or become enlarged, forming small cavities in which termites congregate. Flashlight photograph by E. St. Clair Clayton, November, 1921. *B*, Four typical samples. In one case is seen a large area chewed away with part of insulation also gone. These are duplex telephone 7-strand cables. Holes occurred about every foot or so, the termites getting between the two insulated wires and traveling in this space, eating away part of insulation. Duplex cable measures 19 by 9 millimeters. *C*, Five pieces of duplex lead-covered telephone cable, showing holes made through lead sheathing by termites. *D*, Part of cable covering opened out to show runway of termites between two insulated wires, parts of insulation eaten away to rubber coverings and sometimes even this eaten away. *E*, Part of lead covering chewed away, also portion of insulation. In the second case termites chewed away a flat channel, about 12 inches long, along edge of lead cable. *F*, Another view of *D*, showing eaten-away insulation running whole length of wire in both cases and in one with more extended injury at site of opening. *G*, View of *D* and *F*, with only a portion of lead covering laid open, showing boring as first discovered.

that used in the forms when the locks were built. This timber has no purpose here, and all of it was infested, usually very badly, and nearly all termite galleries ran to some of this wood.

In the long service tunnel, in the center wall, some of the cables run in the space between the ceiling and walls—i. e., a niche was provided for this purpose. Small creosoted (dipped) blocks of wood had been put at regular intervals as wedges to prevent these cables from falling out. Plenty of termite galleries were found in this big tunnel, and in many instances these insects had gone to and were found in these creosoted blocks and did not seem to be repelled by the creosote. The termites had also damaged untreated oak and the native hard "bullet wood" braces.

In one case the termite gallery left one conduit pipe and was continued into space, forming a loop which found no attachment until it reached the lowest point in the next conduit below, and then started to make another loop. (Pl. V, *A*.) The direction was downward. In the tunnel, where one surface is perpendicular to another, cases were observed where the termites on reaching the next wall continued their tunnel into space; such cases were common, but always appeared to be abnormal and due to the conditions encountered. Such galleries were usually branched, as if the termites were trying to locate a surface for attachment.

The writers were told that at light post 750, after the first few rains of the 1921 rainy season, winged termites emerged from two places in the ground. No specimens were collected by the observers, but at a later date specimens were collected and proved to be *Coptotermes niger*. It was said that swallows (not nightjars) came down when this swarming was taking place and fed on these termites, and that they were not frightened by the presence of the men; in fact, that they even moved about between the feet of the men present. The birds not only caught the flying termites while on the wing, but also found the place from which these termites were emerging and, settling on the ground, captured and devoured them as they emerged.

The All America Cables (Inc.) have had trouble with their transisthmian cables due to damage by termites, and the following notes are taken from a conversation with G. W. Wetjen, jr., of this company: The company has a 4-core cable, lead covered, each core with a heavy rubber insulation, the lead covering protected first by a waterproof cloth, and on top of this a heavy waterproof, tough twine. This cable is buried in the ground and in places it goes through the water of the lake. It has been found that when this cable is buried close to the surface they have no trouble from termites, but when it is more than a foot below the ground there is trouble. This trouble is greater where trees are near by. In land reclaimed by filling no trouble has been discovered as yet.[6] The termites go right through the outer waterproof protections, through the lead, and through the rubber. The insects do not seem to like copper, for as soon as they have tried this metal they leave it. In some cases termites were found to be very plentiful, but usually when trouble is "picked up" the insects that caused it have gone or have been dispersed by the men making the preliminary excavations. Soldiers of *Copto-*

[6] Undoubtedly, however, there will be trouble later when the termites have invaded the soil.

termes niger were found in the damaged 4-core cable by Mr. Wetjen near Summit, Canal Zone, in November, 1921. Injury from termites to the company's larger cable, which goes through a concrete duct, has not yet been discovered.

A. Cooper, manager of the Cristobal office of the All America Cables Co., reported another case of damage to their cables by *Coptotermes niger* 5.3 miles south of Cristobal, 660 feet from the nearest splice, and in 2 feet of clay soil. The tape, rubber, and paper insulation were also perforated (Pl. VI, *A*). Workers and soldiers of *Coptotermes niger* were collected from the center wall, Miraflores Locks, Canal Zone, on May 15, 1922, by I. Molino and E. St. Clair Clayton. These termites were damaging lead-covered, 5-core, 7-wire cables, 220 volts, alternating-current, at section 705. In 1 foot there were 7 holes and in the next foot 3 holes. Six feet of cable had to be replaced. Here there was a concrete cover, 2 by 3 feet, over a small well 3 feet deep which communicated with a tunnel used for cables that connected the two side sections, of which No. 705 was one. Under this concrete cover was found some wood used for the forms when the concrete was poured. This was infested with termites.

Specimens of the termites inside of the lead-covered cable were collected as well as those in the wood. Specimens of the infested wood, of the damaged cable, and of damaged insulation (Pl. VI, *B*, *C*, *F*) were collected. All of this damage was caused by *Coptotermes niger*.

This injury to lead-sheathed cables is what might be termed a "local" damage. Such cases are not at all infrequent and occurred also at Pedro Miguel and Gatun. If all the wood had been removed at the proper time, however, there would have been none of this damage.

DAMAGE TO LIVING TREES.

Cases of damage to living trees by *Coptotermes niger* are as follows:

On February 4, 1922, Zetek and Molino collected specimens in avocado trees at Frijoles. Canal Zone. Galleries had been constructed on the trunks of the trees (Pl. VI, *G*). These were rough, made of clay, from 1 inch to $1\frac{1}{4}$ inches wide, and the cavity inside (or hollow) one-eighth inch to three-sixteenths inch in diameter. The termites also worked in the wood of the trunk, and a hole 4 inches deep containing inhabited galleries was observed. Knot holes and poorly pruned places in the trees where rot had already set in were specially sought by these termites. Soldier termites were very abundant.

DESCRIPTION OF PLATE VII.

INTERRELATIONSHIP BETWEEN NEMATODES, THE TERMITE *Coptotermes niger*, AND THE "RED-RING" DISEASE OF COCONUT PALM TREES: *A*, Palm C, Nurses' Quarters, Ancon, C. Z., July 7, 1922. This coconut palm had broken off about 2 feet from the ground and had fallen over between 6 p. m., July 6, and 8 a. m., July 7. *B*, Closer view of same palm, showing break at end of trunk and, at base, upper part of injury through which termites gained entrance into trunk where they had built a secondary termitarium. Part of the trunk at break soft, rot-like in texture, abundantly infested with nematodes. *C*, Smoothed face of section CC (see text fig. 1) of trunk. The red ring is very prominent. Nemas were present in all parts of the section. In the lower right-hand corner is a part of the termitarium. *D*, Covered runways of *C. niger* formed overnight after trunk had been sawed up into four pieces. Larger diameter of trunk about 16 inches. Injury through which termites entered palm is seen in upper part of picture.

On February 16, 1922, these termites were found by Zetek and Molino on a ceiba tree (*Eriodendron casearia* Medic.) at Pedro Miguel, Canal Zone. The galleries on the tree were of mud from one-half to 1½ inches wide, ragged looking, irregular, and flattened; those newly made were very wet and soft, the old ones dry and hard. The portion still under construction appeared to be the site of concentrated effort for a distance of 18 inches, as if the insects were trying to do as much as possible in as short a time as possible. The sides of this newly-constructed gallery were not complete, but had an opening for almost every inch, and at these openings large numbers of termite soldiers stood guard. These soldiers were practically all outside of the gallery, in direct light, with their mandibles wide open; they were aggressive, snapping at anything, and exuding in plenty the viscid white liquid. Inside of the openings were additional soldiers in reserve. As the gallery neared completion, the lower end was finished and all the side openings were closed.

Similar damage to the trunks of living coconut palms occurs (Pl. VI, *D*), and this is discussed in more detail under a subsequent heading (p. 15–16).

SWARMING.

Winged adults of *Coptotermes niger* were collected by E. St. Clair Clayton from the center wall north of the control tower, Miraflores Locks, Canal Zone, from a swarm which occurred on May 28, 1922. They were emerging at about 4.30 p. m., from a small hole in the ground, near a concrete lamp post, at the same place where there was a swarm the year before.

Another swarm of this termite took place in front of the board of health laboratory, Ancon, Canal Zone, at 3 p. m., May 28, 1922. The termites were coming from the crack between the concrete curb and the concrete walk in enormous numbers, the most important feature being the immense number of soldiers which lined the crack and immediate vicinity, remaining on guard as long as winged forms were emerging. The photograph (Pl. VI, *E*) was taken with an upright stand which was focused indoors, and taken outside already set up, since it was raining and the light was poor and unnecessary exposure of the camera to the bad weather was undesirable. Unfortunately, the focus was not sharp enough to give detail at a one-fifth second exposure.

A POSSIBLE MECHANICAL CARRIER OF THE NEMATODE APHELENCHUS COCOPHILUS WHICH CAUSES "RED-RING" DISEASE OF COCONUT PALM TREES.

There is evidence that *Coptotermes niger* may be a mechanical carrier of the nematode which causes "red-ring" disease of living coconut palms. A coconut palm (Pl. VII, *A*), about 5 years old,

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DESCRIPTION OF PLATE VIII.

INTERRELATIONSHIP BETWEEN NEMATODES, THE TERMITE *Coptotermes niger*, AND THE "RED-RING" DISEASE OF COCONUT PALMS: *A*, Covered runway of termite built overnight after trunk was sawed up into four pieces. At lower end is seen part of termitarium which had been cut through during sawing. The characteristic ring of the disease is very evident. This section is lower face of CC of the diagram (text fig. 1). *B*, View of termitarium of termite found within trunk of palm. The tissues were abundantly infested with *Aphelenchus cocophilus*. No queen cells were found; only soldiers and workers were present. *C*, Another view of same termitarium. Note cylindrical runways of termites going into trunk tissues. *D, E*, Other views of same termitarium.

growing near the nurses' quarters at Ancon Hospital, Ancon, Canal Zone, and transplanted to this location about three years before, was inoculated with live nemas (*Aphelenchus cocophilus*) January 10, 1922, by Dr. N. A. Cobb, with the assistance of Mr. Zetek. Since Doctor Cobb left a few days later, the observations on the progress of

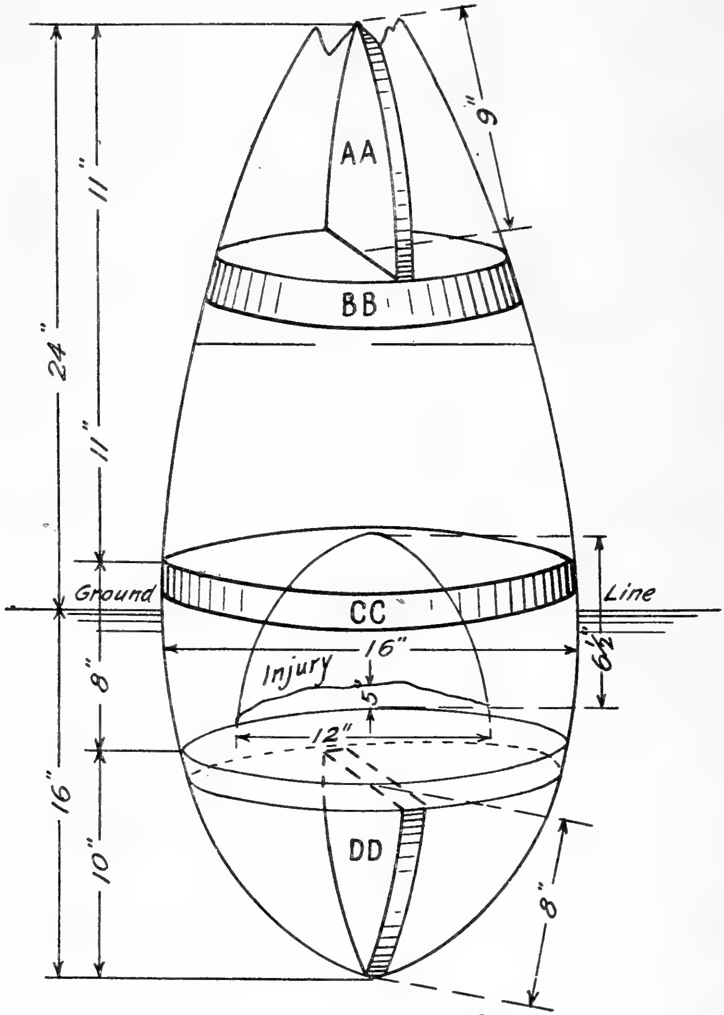
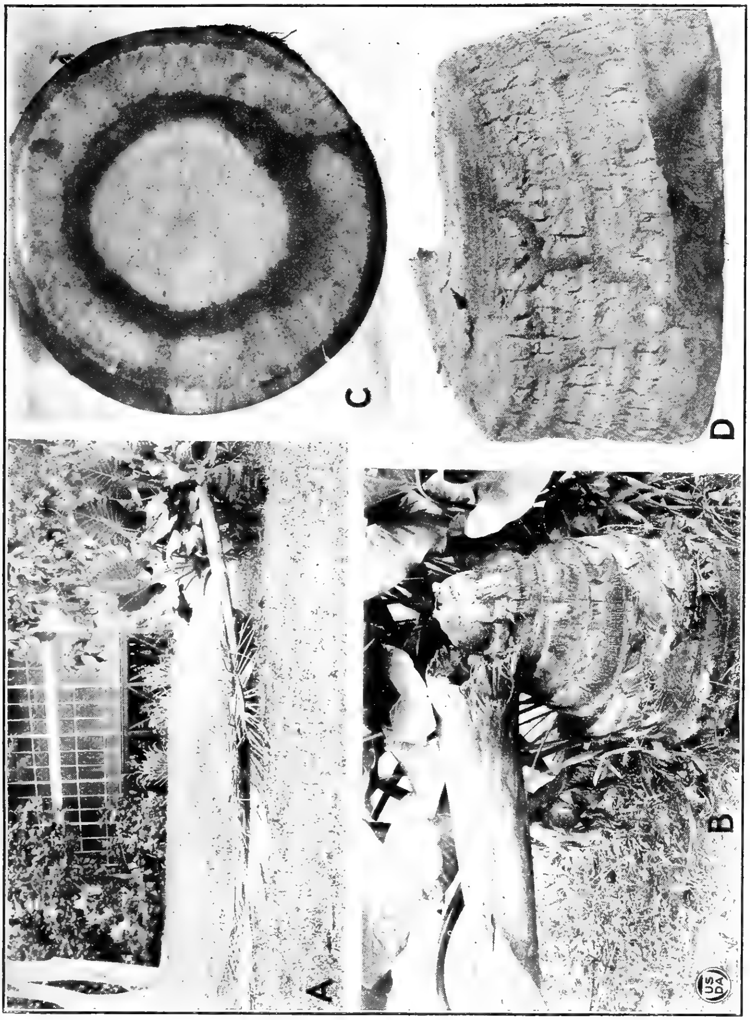


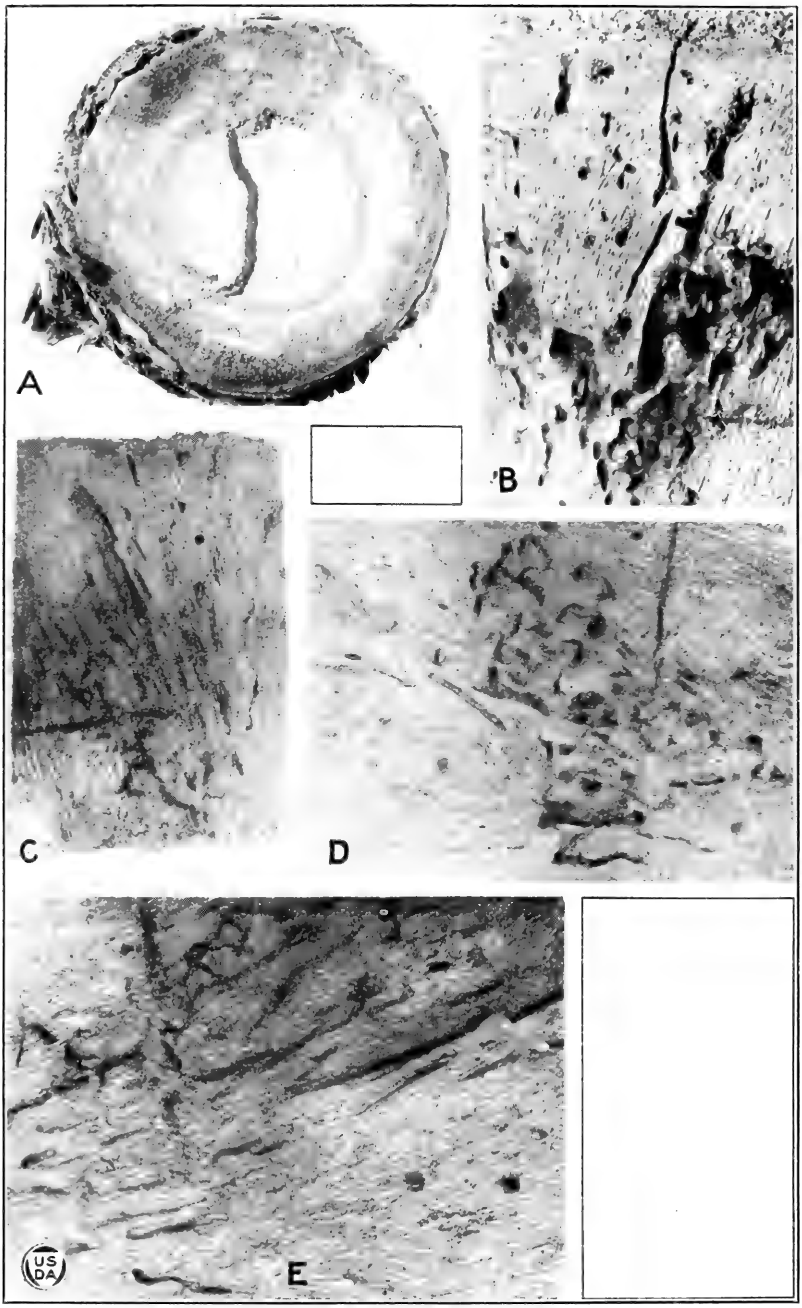
FIG. 1.—Diagram to show general shape and size of trunk of coconut palm shown in Plate VII, its relation to ground level, and location of four sections that were cut and photographed. Location of injury through which termites entered is also shown.

the disease were made by Mr. Zetek, assisted by Mr. Molino. The inoculation was made under aseptic conditions into two petioles and live nemas, free in a little water, were used. When transplanted the tree was placed too deep in the ground, but it was growing very well.



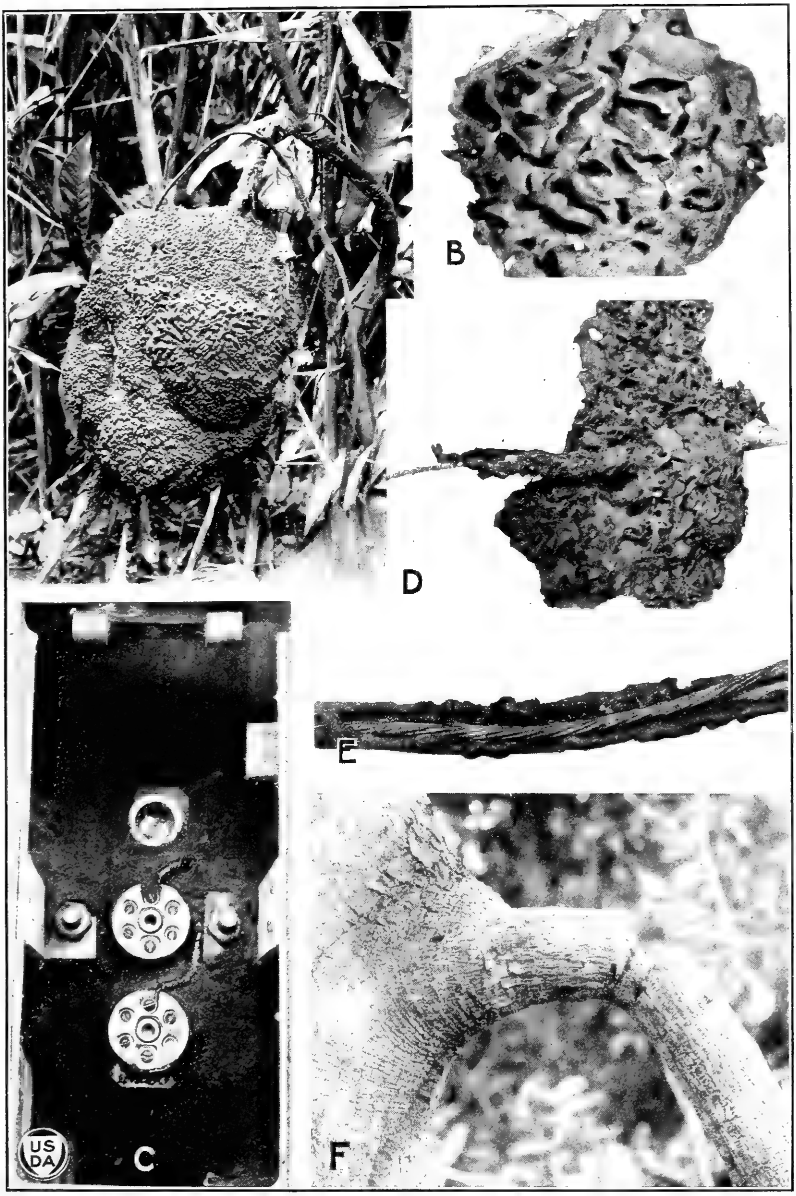
INTERRELATIONSHIP BETWEEN NEMATODES, THE TERMITE COPTOTERMES NIGER, AND THE "RED-RING" DISEASE OF COCONUT PALMS.

Description at foot of page 13.



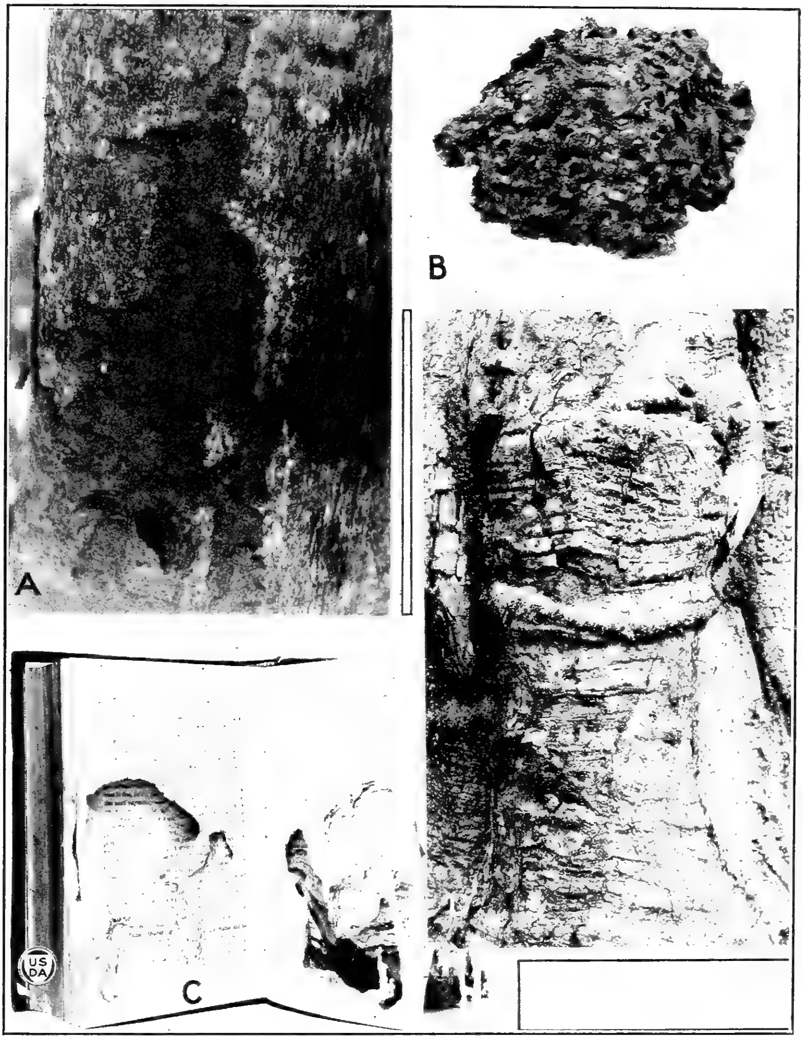
INTERRELATIONSHIP BETWEEN NEMATODES, THE TERMITE COPTOTERMES NIGER, AND THE "RED-RING" DISEASE OF COCONUT PALMS.

Description at foot of page 15.



CARTON NESTS AND SHELTER TUBES OF NASUTITERMES CORNIGERA AND INJURY TO ELECTRICAL APPARATUS BY N. EPHRATÆ.

Description at foot of page 17.



SHELTER TUNNELS AND NEST STRUCTURES AND DAMAGE BY TERMITES, ALSO THE TERMITELIKE SHELTER TUNNELS OF AN ANT.

A, Shelter tubes of *Nasutitermes columbicus* on avocado tree, Frijoles, C. Z. *B*, Part of nest structure of a termitarium of *Eutermes debilis* in crotch of tree on Taboga Island, R. P. *C*, One volume of LaSalle University law books, badly damaged by termites, on shelf in room. Three volumes were attacked. The damage seems to have been done in one week's time. *D*, Shelter tubes of an ant similar to those constructed by termites. Photographs by Zetek.

The history of the palm following inoculation was as follows: At first there was no indication of anything wrong inside. Then came a sudden rapid growth, which lasted a very brief time. The palm then took on an unhealthy appearance, which became more and more evident, so that people unaware of what had been done to the palm remarked that it did not look well. Early in June there was a browning and drying out of the tips of the leaflets, beginning with those nearest the apex and gradually working downward. The final collapse came July 7, i. e., almost six months after the inoculation, the palm breaking off 2 feet from the ground level.

The photographs show the palm after it had fallen. The close-up of the trunk (Pl. VII, *B*) shows at the base a slanting injury. The extent of this wound is better shown in the accompanying sketch (fig. 1), which gives the size and shape of the trunk, relation to ground level, and the location, size, and shape of the wound. This wound is of importance because it afforded entrance to termites. During the time the palm was being watched this wound was suspected of harboring termites, but there were no outward indications of their presence, and to have cut into the injury in search of them would have interfered with the experiment. There were no galleries up the palm trunk, but, as was discovered later, termites were present inside, having come up through the earth.

The termites were very abundant inside of the trunk, where they had formed a well-defined termitarium. Only soldiers and workers were present, however, and there were no signs of queen chambers. Five photographs were taken of a section through this termitarium which illustrate well its character (Pls. VII and VIII). Special attention is called to the runways in the shape of holes (Pl. VIII, *B*, *C*, *D*, *E*). At the widest part of the termitarium the termites filled about one-third the width of the trunk, or about 6 inches, but their tubular runways went to all parts, although none were seen as far up as *BB* of the sketch (fig. 1).

All of the tissue of the termitarium was abundantly supplied with live nemas. Individual termites were carefully picked up and washed in water, and by this means many live nemas which had been clinging to their bodies were recovered.

Since these termites had only a secondary termitarium in this palm, they must have had the main one elsewhere, and probably members of this same colony visited other palms in the neighborhood. The possibility of mechanical transmission of nemas to healthy palms by the termites is thus seen to be great. They may be carried in any stage, including eggs. Likewise, since in this case nemas were also in the roots, and it has been shown that nemas will live in the soil about an infested palm, termites are well able to become soiled with live nemas in the earth, and thus bring the infection to other palms.

The photo of section *CC* (Pl. VII, *C*), which is the upper side, shows a part of the termitarium (indicated by an arrow).

After the trunk had been cut into four parts, as shown in the sketch (fig. 1) (10 inches, 8 inches, 11 inches, and 11 inches), at 4 p. m., July 7, 1922, the four segments were left in the room till next day. At 8 a. m., July 8, Zetek found along the face of the second section (from top) a covered runway or gallery 7 inches

long built by these termites during the interval. A photograph was taken of this newly made gallery (Pl. VIII, *A*). Soldiers were on guard at the openings of this gallery.

There was also a gallery along the sides of the third section (from top); it measured 6 inches in length (Pl. VII, *D*). The wound is shown in the photograph of this segment. Section *CC* was cut from the top of this particular section.

No termites were found in section *DD* (fig.1).

COMPOSITION OF SHELTER TUBES.

A microchemical examination by the Bureau of Chemistry of the United States Department of Agriculture of fragments of the shelter tubes constructed by *Coptotermes niger* from galleries in the center wall of Miraflores Locks, Canal Zone, is reported as follows:

Sample *B*, M. 38192. This sample was found to contain an appreciable amount of siliceous material, and also material giving the usual microchemical reaction for lignin, as well as showing evidence of definite cellular structure, thus differing from sample *A*, where similar material was more finely comminuted.

NASUTITERMES CORNIGERA Motschulsky.

The bad-smelling *Nasutitermes cornigera* is one of the most common and destructive termites in Panama, and its semispherical, "niggerhead," carton nests on the trunks or in the crotches of trees are often found.

On July 26, 1921, Zetek and Molino found this termite very abundant on trees along the Tumba Muerta road, near Panama City, from Las Sabanas road to Corundu River, a distance of about 1½ miles, it being the prevalent species. Citrus trees especially were badly infested. At Octavio Icaza's place nearly all the citrus trees had nests of this termite in the crotches. At Herbruger's place (La Loceria) all the citrus trees were infested with this species, which was very abundant and in two cases had apparently caused the death of the trees.

Earthlike galleries one-half to 1 inch wide and one-fourth to three-fourths inch thick were abundant on the tree trunks along the road referred to and nests in the trees were not rare. No queens were found, the nests containing mostly soldiers. In one case at La Loceria (near Panama City) on a citrus tree soldiers were seen crawling about and also exposed on the ground with no gallery or anything to protect them. A distance of about 4 feet was traversed in this manner.

Some of the nests on trees were as large as 2 feet by 3 feet.

DESCRIPTION OF PLATE IX.

CARTON NESTS AND SHELTER TUBES OF *Nasutitermes cornigera* AND INJURY TO ELECTRICAL APPARATUS BY *N. ephratae*; *A*, Large semispherical carton nest of *N. cornigera* at Miraflores Locks, C. Z. *B*, Structure of termitarium inside of bronze service box in Lamp Post No. 600, Miraflores Locks, C. Z. November 29, 1921. *C*, Termitarium of *N. ephratae* in hollow center of Lamp Post No. 600, Miraflores Locks, enveloping the wires, light socket, and two telephone sockets in bronze service box. There were, back of this nest, a few pieces of pine boards infested with this termite. November 29, 1921. *D*, A lead-covered 600-volt copper wire with termitarium about it. This termite does not eat into the lead, but does destroy all cloth and rubber insulation. Where the copper is laid bare the termites have formed a sheath over it. November 29, 1921. *E*, Damage done to braid and rubber insulation of 600-volt wires leading to overhead lights at Lamp Post No. 600, Miraflores, C. Z. *F*, Shelter tube of *N. cornigera* on branch of avocado tree showing work of a girdling beetle, *Trachydares subpilosus*.

These termites were also very abundant on fence posts along the same road on July 26. Hardly any posts were without their galleries and in many cases had carton nests as well. Soldiers in the main were seen and there were no queens.

Zetek and Molino found *Nasutitermes cornigera* in a wine palm (*Acrocomia vinifera*) at Ancon Hospital on October 26, 1921. These termites were very abundant throughout the wood of the trunk and along the midrib of fronds. Soldiers came out rapidly when the trunk was tapped with a piece of wood. Small nestlike structures were found sheltered by the pieces of leaves and bark, as also nests at the base of leaves; all these were soft and crumbly in texture.

On November 3, 1921, a nest of *Nasutitermes cornigera* was found in *Ficus crassiuscula* at Ancon Hospital, Canal Zone. The nasuti were very abundant.

A termitarium of this species was found in the top of a jobo tree (*Spondias lutea* L.) at Ancon Hospital, Canal Zone, on November 23, 1921. Galleries, which were fairly straight, were abundant, the narrowest one being about three-eighths of an inch wide, the largest 2 inches broad by one-half inch thick. The small ones joined to form wide ones. In the galleries nasuti or soldiers were very abundant and workers very few. This termite has a very pungent, disagreeable odor. When the soldiers were grasped or touched they emitted a milky fluid from the opening of the frontal gland or end of the nasus or beak. In many cases this shot out into space as a small droplet, the distance it was propelled in many cases being 1 foot. It did not seem to have any irritating effect on the skin.

At Miraflores, on November 29, 1921, Zetek and Molino found a termitarium of *Nasutitermes cornigera* on a tree on a small island near the locks. This termitarium was 12 inches by 18 inches in dimensions and had numerous galleries along neighboring branches (Pl. IX, *A*). Nasuti were very abundant in it. Zetek found it to be very hard and difficult to break up, although the machete he used was sharp and some impression could be made upon it with every cut. At the third blow, however, the machete glanced off and just missed badly cutting his foot.

On February 4, 1922, at Frijoles, Canal Zone, Zetek took an interesting photograph (Pl. IX, *F*) of a gallery of *Nasutitermes cornigera* on an avocado limb, showing the work of a girdling beetle, *Trachydares subpilosus* Bates.

A nest of this species in process of construction was found on April 1, 1922, in an avocado tree on Taboga Island, Republic of Panama.

From the foregoing it will be seen that *Nasutitermes cornigera* builds its carton nests in a variety of trees and is an injurious termite.

SWARMING.

Winged adults of *Nasutitermes cornigera* were collected flying in a house in Chitre, Republic of Panama, during the afternoon of May 7, 1922, during a heavy rain—the first of the rainy season at this locality.

NASUTITERMES EPHRATAE Holmgren.

Nasutitermes ephratae is very destructive in Panama, although apparently not quite as common as *N. cornigera.* Out-of-door, semispherical, "niggerhead," carton tree nests constructed of earth and excreted wood made by this species are apparently very rare in Panama.

At the Venado Plantation, Venado, Canal Zone, on August 10, 1921, Zetek and Molino found that almost all the coconut palms had tunnels of Nasutitermes on the trunks. Many palms had fairly large nests on the trunks just below the crown, where they were protected by the "lace." These termites also work freely between the sheaths of the frond petioles, mining well into the plant tissues of the trunk. They are very destructive and do not seem to confine their attack to sickly trees, but apparently any palm may be infested. They are abundant also on other trees in this grove. Workers and soldiers collected from a gallery proved to be *N. ephratae.*

INJURY TO ELECTRICAL INSULATION.

This termite has also affected electrical insulation. On November 29, 1921, a typical Nasutitermes termitarium, probably a secondary "nest," was discovered in a service box in a lamp-post. Specimens of the termites were collected by Zetek and Molino, with the assistance of E. St. Clair Clayton, who discovered the place, at Miraflores, Canal Zone, east wall, lake section, in concrete lamp-post No. 600.

These concrete lamp-posts have a bronze service box in which are two sockets for telephone service and one socket for a portable 110-volt light. They are covered with a bronze cover. The interior of the post is hollow. The wires to the telephone and light services come from a manhole opposite the post. In this case, this being the end post, the manhole is only about 2 feet deep. *Leucotermes tenuis* was collected in this service manhole.

The termitarium was back of the frame on which the telephone and light sockets were attached. It embraced all of the five wires and even covered parts of the frame and sockets (Pl. IX, *C*). This termitarium was about 15 inches in diameter and about 3 feet tall. The photograph of this service box shows only a portion of the nest.

The termites did not eat into the lead anywhere, although where the cable went through the termitarium the insects made a smooth whitish covering about it (Pl. VII, *B*). However, the cloth and rubber insulation were eaten, as was the weatherproofed braid from the wires leading to the overhead lights (Pl. IX, *E*). They do not care for copper and usually when the copper was made bare, they protected themselves from it by forming a sort of sheath of the same substance as the rest of the termitarium (Pl. VII, *D*). Much of this exposed copper wire was covered with verdigris.

The thickness of the rubber protection is almost 1.5 millimeters.

As soon as the nest was opened in the least, hordes of nasuti or soldiers came out to investigate. Whenever any one of these was touched or picked up with forceps, it emitted a drop of whitish liquid; sometimes it was squirted out, falling about 9 or 10 inches

away from the insect. There is a very pungent, nauseating odor about these termites.

No queens were found, although practically every bit of the nest was examined carefully. The number of workers and soldiers was simply stupendous. They walk either forward or backward with considerable speed. When uncovered on the ground, they crawl away in several columns, two or three termites abreast, and seek some dark place, into which they pour in great numbers.

Several pockets were found in the nest in which were a large number of very young termites. When these were disturbed certain workers began to pick them up and hasten away with them.

Specimens of this termite were also taken from galleries at the base of lamp-post 600 and were probably part of the nest in the service box.

POSSIBLE MECHANICAL CARRIAGE OF NEMATODE.

On February 23, 1922, Zetek and Molino found this termite working inside of the trunk of a 4-year-old live coconut palm (*Cocos nucifera*) back of house 259, Ancon, Canal Zone. This is an important observation, because Dr. N. A. Cobb, agricultural technologist of the United States Department of Agriculture, and Mr. Zetek had made inoculations into the roots and some petioles of this palm of the nematode *Aphelenchus cocophilus*, which causes "red-ring" disease of coconut palms. Later, when some of the infested roots were taken up, workers and nasuti of this termite were found. Thus species of Nasutitermes may prove to be mechanical carriers of this nematode.

It is a common sight in the Tropics and subtropics to see earthlike shelter galleries and carton "niggerhead" nests made by species of Nasutitermes on the trunks of coconut palms, the tubes running from base to crown like delicate graceful dark pencilings on the trunks and the nest often being in the tops of the trees. These termites also burrow into the wood of the trunks and sometimes in the West Indies the queen is in the wood of the tree rather than within the carton nest. Hence, if it should be proved that these termites are mechanical carriers of the nema, it would be a serious matter to eradicate them. Doctor Cobb kindly examined specimens of workers and soldiers of *Nasutitermes ephratae* taken from this infested palm at Ancon, but found no trace of the nematode *Aphelenchus cocophilus*. He says: "I think that you are right in suspecting that these ants might be carriers of this nema. Their habits would seem to put them under suspicion, but, at any rate in this case, they do not seem to have been carrying them."

Workers and nasuti of this termite were collected on a live fan palm on May 29, 1922, at Matias Hernandez, by Zetek.

A first-form queen of *Nasutitermes ephratae* collected in a small carton tree nest on a mango tree in an avocado plantation at Frijoles, Canal Zone, on February 19, 1921, by Zetek and Molino, measured 21 millimeters in length and 4.5 millimeters in width.

A large elliptical termitarium of *Nasutitermes ephratae*, 2 feet by 1½ feet in size, with tunnels leading to it, was found attached to the base of two petioles of a coconut palm at Corozal, Canal Zone, in a small coconut grove about 8 years old. On the ground was an-

other such termitarium, inhabited and almost as large, which, it appears, had been torn off of the tree by some men and left on the ground.

In the termitarium on the trunk were found soldiers (the most abundant form), then workers and young, and finally, all in one place but each within its own compartment, seven large, distended queens 19 to 23 millimeters in length and 4.5 millimeters in width. When disturbed, worker and soldier termites came to the queens and covered them up while others started to move them away to shelter.

The nest on the ground contained no queens, but was well inhabited with soldiers and workers, the former being most numerous.

Workers and soldiers of this termite, the latter very abundant, were found by Zetek and Molino in galleries on the trunk of a coconut palm at Corozal, Canal Zone, July 19, 1922, in the grove previously mentioned. The galleries, samples of which were saved, were from one-half to three-fourths inch wide, thin, and made of chewed wood.

This species works within the wood, and in numerous places holes were found leading into the palm trunk. The galleries all led to the top or crown of the palm, and were even sprawled over the petioles.

Most of the palms had termite tunnels of some sort, including small, narrow ones, one-fourth inch wide, made by *Eutermes* sp. Workers were found by Zetek and Molino in these small earthen galleries on the trunk of a coconut palm at Corozal, Canal Zone, July 19, 1922, in the same grove.

COMPOSITION OF SHELTER TUBES.

A microchemical examination of these shelter tubes of *N. ephrătae* by the United States Bureau of Chemistry resulted in the following report:

Nasutitermes ephratae (M. 38248). The material submitted under this number was found to consist essentially of plant material, part of which gave the usual microchemical reaction for lignin. Siliceous material was practically absent.

NASUTITERMES COLUMBICUS Holmgren.

Nasutitermes columbicus apparently does not construct regular semispherical carton tree nests, but otherwise it does not differ in habits from *N. cornigera* and *N. ephratae*.

On October 25, 1921, at Frijoles, Canal Zone, Zetek and Molino found this termite on the trunk of an avocado tree. A vine grew along the tree trunk and was completely hollowed out by the termites. There were galleries along the trunk of the tree, but the termites did not enter the avocado wood. On the ground the tunnels were uncovered; these galleries were semicircular, three-fourths to three-eighths inch wide, and as much as three-eighths inch in height; they were of fine red granular dirt, thin, very fragile, of paperlike consistence. Termites were crawling about uncovered everywhere on the ground.

Nasutitermes columbicus also enters the wood of avocado trees. At Frijoles, Canal Zone, on February 4, 1922, galleries of this termite were found on an avocado tree (Plate X, *A*). These galleries were paperlike in texture, thin, and gray; they measured one-half

inch in width, and several galleries often coalesced to form a wide, flat one, 4 to 5 inches wide. The termites were also working inside of the wood, even in sound wood; in one place a termitarium of a sort was observed in the wood, but no queens were found.

SUBULITERMES ZETEKI Snyder.

This is a very interesting, odd appearing, nasutiform termite, but as yet little is known of its habits. The first record of this genus occurring in Central America was the capture of this species, named after J. Zetek, by Zetek and Molino at Summit, Canal Zone, on July 29, 1922. Workers and soldiers were found abundant in the trunk and petiole of an oil palm (*Elaeis melanococca*).

No species of Subulitermes occurs in the Dudley collection of Panama termites at the Museum of Comparative Zoology at Cambridge, Mass., nor in the Beaumont collection at the American Museum of Natural History in New York City.

EUTERMES DEBILIS Heer.

As yet little is known of the habits of *Eutermes debilis* in Panama. It has been found only on the Pacific slope. *E. debilis* builds earth-like galleries and earthen nests on the trunks of trees, including coconut palms. It is a wood borer.

At Ancon Hospital on October 26, 1921, Zetek and Molino found workers and soldiers of this termite in a tall tree. The whole trunk was covered with tortuous, light-brown to gray galleries, one-eighth to three-sixteenths inch wide. These galleries were of earth, firm, and often with algal growth over them. There was no nest, and the termites were few in number. Soldiers were scarce.

A nest found in the crotch of a mango tree on Taboga Island, Republic of Panama, on March 30, 1922, by Zetek and Molino was of hard clay (Pl. X, *B*) and of about one-fifth cubic foot content. Only one soldier was found; but workers were very abundant, as well as nymphs of the sexual forms with rudimentary wing pads. Two lots of eggs were found in oblong, shallow cells. A large first-form queen, with distended abdomen, was present. This queen is 21 millimeters in length and 4.5 millimeters in width.

On April 1 another nest of this species was found on Taboga Island in an orange tree, but few termites were present.

This termite is supposed to construct its nests and shelter tubes of dirt alone. However, fragments of shelter tubes of *Eutermes debilis* from the trunk of a tree at Ancon, Canal Zone, were examined by the Bureau of Chemistry with the following result:

Sample *A*, M. 38191: This sample was found to contain an appreciable amount of siliceous material and also finely comminuted material which gave the usual microchemical reaction for lignin, but did not show any evidence of cellular structure.

It was remarked by the microanalyst that "apparently the so-called dirt in this instance may be in part decayed plant material, as the presence of lignified material would seem to indicate."

ANOPLOTERMES GRACILIS Snyder.

Very little is known of the habits of *Anoplotermes gracilis*. Apparently it does not construct a regular mound nest.

On February 18, 1922, Zetek collected workers and nymphs of the first form at Alhajuela, Republic of Panama, on the upper Chagres River basin. They were in claylike dirt under a stone at the base of a mango tree. There was no well-defined termitarium; the termites lived in burrows made in the clay. The long, white, slender nymphs were agile and moved about with ease. The termites did not penetrate the wood of the tree, so far as could be observed; their guts were filled with dirt.

TERMITE-LIKE SHELTER TUBES OF AN ANT.

In connection with the earthlike shelter tubes constructed by various species of termites, it is interesting to note that in Panama an ant forms termite-like carton shelter galleries along tree trunks (Pl. X, *D*). Specimens of this ant and the gallery substance were collected by Zetek and Molino on November 16, 1921, at Valdez's Place, Las Sabanas, near Panama City, Republic of Panama. This ant has been determined by Dr. W. M. Wheeler, of Bussey Institute, Harvard University, as *Azteca foreli* Emery.

The tree with these ant galleries on it was an old *Ficus* sp. about 8 feet in diameter, the top of it cut off squarely. The inside of the tree was well rotted. Along the outside (the bark was sound) ran many galleries, three-eighths to three-fourths inch in diameter, which at first sight looked like those of termites. They were, however, rough in appearance and very irregular in outline and were made of chewed-up pieces of wood. The inner surface is smoother, the outer rough. The old ones were colored by age, so that they resembled the color of the bark and even had algæ growing over them. The new galleries were distinctly of fresh-wood color. The ants were found wherever the tunnels were broken into, but there were a few places where the ants were unusually abundant. There were no signs of termites in the tree at the time.

Doctor Wheeler wrote:

> Before the ants arrived I was certain from his (Zetek's) description of the galleries that the specimens would prove to be *Cremastogaster stolli* Forel, but when they arrived I found that they were instead *Azteca foreli* Emery. I still believe that the galleries were probably constructed by the Cremastogaster, because I am quite familiar with that insect and its work, but that the Azteca had taken possession of them.

Doctor Wheeler further states that Forel (*4, p. 111*) was also of the opinion that these carton galleries on trees and rocks are really made by *Cremastogaster stolli*, but appropriated by *Azteca foreli*.

CONTROL.

Methods for the prevention of attack by termites have been given in some detail in a previous paper (*2, p. 300–301*). To generalize briefly:

In the construction of buildings or other structures, steel and stone or concrete should, where possible, supplant wood. All wood should be treated with chemical wood preservatives before being

placed in situ. Wooden forms should be removed after the concrete has hardened; when left, they become infested, and this leads to damage to woodwork, lead cables, etc. Where timber is to be used in contact with the ground, it should be impregnated with coal-tar creosote. The interior woodwork of buildings should also be impregnated with chemical wood preservatives; zinc chlorid, bichlorid of mercury, and chlorinated naphthalene[7] will protect wood from attack by termites, unless the situation is very damp, when the soluble chemicals, zinc chlorid and bichlorid of mercury, will leach out (*7*).

In the Philippine Islands a termite or "anay" exterminator has been found successful (*1, p. 58–59*). The method is as follows: To a 5-gallon can of kerosene oil, add 100 cubic centimeters of a saturated mixture of white arsenic in hydrochloric acid (HCL) (about 1 part acid to 1 part water). Tilt can so arsenic solution gathers at one corner. Then add 50 cubic centimeters concentrated sulphuric acid (H_2SO_4) which will withdraw water from the hydrochloric acid and will saturate the kerosene with hydrochloric-acid gas containing arsenic trichlorid. *This process is dangerous and should be done out in the open, and the operator must avoid breathing the fumes produced.* The process is completed after the reaction is stopped, and the solution is then ready for use. It is applied by painting or spraying on wood surfaces. Parts not exposed should be exposed and treated; it may also be injected into wood. Since this mixture will corrode the kerosene tin, it should be stored in a glass demijohn.

No wood known to the writers is immune to attack by termites, but there are many termite-resistant woods, and these should be used wherever possible. The heartwood of teak (*Tectona grandis*) from Siam and Burma; sal (*Shorea robusta*) of India; cypress pine (*Callitris robusta*) of Queensland, Australia; Foochow cedar (*Cunninghamia sinensis*) of China; Randai cedar (*Cunninghamia konishii*) of Formosa; greenheart (*Nectandra rodioei*) of South America; redwood (*Sequoia sempervirens*), incense cedar (*Libocedrus decurrens*), giant arborvitae or western red cedar (*Thuja plicata*),[8] and junipers or red cedars (*Juniperus* spp.) of the United States are woods which are very resistant to attack by termites, and there are many other such species.

Oshima (*6*) states that the resistance of the timbers which he tested to attack by termites is due to the presence of a sesquiterpene alcohol in the wood.

In the case of the subterranean mound-building termites, in addition to the remedial measures advocated by Dietz and Snyder (*2, p. 301*), it might be well to experiment with chloropicrin, one of the gases used with success in the World War. Feytaud (*3*) states that he has used this effectively in France against *Reticulitermes lucifugus* Rossi infesting the woodwork of buildings. Paradichlorobenzene might also prove effective in killing termites which construct

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[7] The chlorinated naphthalene used in these tests is a mixture of various chlorinations as well as free naphthalene, with a large preponderance, however, of tri chlor naphthalene. This material is usually referred to as tri chlor naphthalene, and as compared with other chemicals it is really comparable to a technical product having naphthalene, mono chloro naphthalene, di chlor naphthalene, and probably some of the higher chlorinations as impurities. Its melting point ranges between 190° and 210° F. This is the specification under which it is sold.

[8] Red cedar poles are badly attacked by Katotermes in California.

mound nests or which have underground galleries with well-defined openings. This chemical is a coal-tar product made by combining benzol and chlorine gas. Crystals could be placed in the openings of the nests or mounds and thus kill subterranean termites. However, where a large number of termite mounds occur on land intended for cultivation, the land can be cleared by the use of steam shovels or by exploding the mounds with dynamite and crushing them by a heavy gasoline caterpillar tractor. The soil can then be sprayed with sodium cyanid to kill the termites, using 160 pounds of granular sodium cyanid per acre with 12,000 gallons of water, as recommended for the Japanese beetle (*Popillia japonica* Newm.), or quicklime, wood ash, or lye used.

Species in the family Kalotermitidae probably can be practically controlled by the use of dry heat. In the attic of the Royal Palm Hotel, a large, high, frame structure at Miami, Fla., the temperature becomes very high, due to the subtropical heat and also to the fact that the sun's rays beat down on the roof; the temperature in the attic was from 17° to 24° F. higher than the maximum temperature recorded by the United States Weather Bureau. Oak and maple furniture infested with the destructive West Indian termite *Cryptotermes brevis* Walker, which had been removed from guest rooms and placed in this attic directly under the roof, contained no living termites when examined in the latter part of January and early part of February, 1922, by T. E. Snyder. Small piles of pellets under this furniture indicated that the termites had continued to work in the infested furniture for a short period after having been removed to the attic, where undoubtedly the temperature became too great even for a termite that normally lives in hard dry wood, i. e., in wood which probably contains normally only about 10 per cent of moisture.

O'Kane and Osgood (*5*) were successful in killing the earth-inhabiting termite *Reticulitermes flavipes* Kol. which was infesting the woodwork of a large hospital at Dover, N. H., by the use of supplementary steam piping and maintaining a temperature of 135° F. for 24 hours.

Fumigation with hydrocyanic-acid gas will kill species of Kalotermitidae infesting woodwork of buildings or furniture. Twelve ounces of sodium cyanid per 1,000 cubic feet was successfully used in killing *Cryptotermes brevis* Walker infesting woodwork and furniture in case of the Royal Palm Hotel at Miami, after the building had been sealed; the gas remained in the building for about 48 hours.

In order to kill termites of the family Kalotermitidae which work in dry wood and have no connection with the ground, various mixtures can be used. A 20 to 30 per cent solution of paradichlorobenzene in kerosene (or orthodichlorobenzene, a similar chemical) can be used effectively.

The infested wood is saturated with this liquid by swabbing it with a mop. Several treatments may be necessary to enable the chemicals to penetrate the wood and kill the insects therein. A poisoned kerosene-emulsion mixture can be similarly used by dissolving 1 ounce of sodium arsenite in each gallon of the water used for diluting stock mixtures of kerosene emulsion or miscible oil.

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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Washington Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1235

Washington, D. C. November 28, 1924

LIFE HISTORY OF THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

By

E. J. NEWCOMER, Entomologist, and W. D. WHITCOMB, Assistant Entomologist,

Fruit Insect Investigations, Bureau of Entomology

CONTENTS

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LIFE HISTORY OF THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON.[1]

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CONTENTS.

INTRODUCTION.

The codling moth, *Carpocapsa pomonella* L., is the most serious insect pest with which the apple growers of Washington have to contend. Previous to 1915, little trouble had been experienced in controlling this pest, but in the years 1915 to 1918, inclusive, losses from wormy apples increased, more difficulty being experienced in the region about Yakima than in the other important apple-growing regions of the State. This led the Bureau of Entomology, United States Department of Agriculture, at the request of the department of agriculture of the State, to establish a field station at Yakima, in the spring of 1919, for the purpose of making a careful study of the codling moth in Washington.[2]

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[1] With notes on the life history in the Wenatchee Valley of Washington.

[2] The work was done under the direction of Dr. A. L. Quaintance, in charge of Fruit Insect Investigations, Bureau of Entomology, in cooperation with the Washington Agricultural Experiment Station. The senior author was placed in immediate charge of the work at Yakima, and was assisted throughout the investigations by the junior author. During the summer of 1920, Miss Sadie E. Keen, now with the Bureau of Entomology, assisted temporarily with the life-history investigations. Valuable assistance and information were given at various times by members of the Washington State department of agriculture, particularly by those located at Yakima in the capacity of horticultural inspectors.

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THE YAKIMA VALLEY.

The Yakima Valley of Washington, in a broad sense, includes several valleys along the Yakima River on the east slope of the Cascade Mountains. These are situated in Kittitas, Yakima, and Benton Counties. The Kittitas Valley, about Ellensburg, has an elevation of about 1,500 feet, and little of it is devoted to fruit raising. Following down the river the next valley is the Selah Valley, only a few miles square, and below this is the upper Yakima Valley, with its tributary districts, the Naches Valley and the Tieton section. These are all intensively planted to fruit orchards, consisting mostly of apples, and the elevation varies from approximately 1,000 feet above sea level at Yakima to 2,000 feet at Tieton. Passing through a narrow gap in a range of hills below the city of Yakima, the river enters the lower Yakima Valley, which is much larger than the others. It is approximately 55 miles long, and varies in width from 2 to 25 miles. The high ground east of the Yakima River is devoted largely to orchards, while the area west of the river, which is almost wholly included in the Yakima Indian Reservation, is mostly given over to the raising of hay, grain, and other field crops, though there are some orchards.

Practically all of the cropped land in this naturally arid region is irrigated by means of water taken from the Yakima, Tieton, and Naches Rivers. According to the Yakima Commercial Club, there is a total of 240,000 acres of irrigated land in crops in the Yakima Valley, exclusive of the Kittitas Valley. Of this, approximately 50,000 acres are in fruit. The tree census of Washington State department of agriculture shows that in 1918 there were about 2,000,000 apple trees, 500,000 pear trees, and 500,000 other fruit trees in Yakima County.

The climate of the Yakima Valley is dry, with a normal annual rainfall of from 7 to 9 inches, the distribution of which is shown in Table 1. During the summer the daily range of temperature is relatively great, often being 30°, and sometimes more than 40° F. A considerable amount of wind is experienced during the spring and early summer, which is doubtless a factor in distributing the codling moth from one orchard to another. Table 1, taken from published data of the United States Weather Bureau, gives further details as to the weather during the years this investigation was in progress.

TABLE 1.—*Annual meteorological summary, Yakima, Wash.*

1919.

Month.	Temperature (°F.). Means. Maximum.	Means. Minimum.	Means. Monthly.	Extremes. Highest.	Extremes. Date.	Extremes. Lowest.	Extremes. Date.	Greatest daily range.	Precipitation (inches). Total.	Greatest in 24 hours.	Total snowfall (unmelted).	Number of days. Precipitation (0.01 inch or more).	Maximum temperature. 32° or below.	Maximum temperature. 90° or above.	Minimum temperature. 32° or below.	Minimum temperature. 0° or below.	Prevailing direction of wind.
January	39.4	20.9	30.2	60	22	4	[1] 4	36	1.00	0.41	4.3	8	10	0	28	0	NW.
February	45.0	25.9	35.4	56	28	16	[1] 2	29	.99	.33	6.8	12	0	0	28	0	NW.
March	59.1	31.8	45.4	75	29	24	[1] 3	44	.10	.05	T.	4	0	0	18	0	NW.
April	67.9	39.1	53.5	83	27	26	11	39	.38	.25	0	2	0	0	6	0	NW.
May	73.8	43.4	58.6	92	21	32	30	45	.58	.33	0	4	0	1	1	0	NW.
June	79.9	47.2	63.6	94	19	35	10	44	.04	.04	0	1	0	3	0	0	NW.
July	80.6	55.5	72.6	104	15	42	[1] 6	46	.03	.03	0	1	0	18	0	0	NW.
August	88.8	54.1	71.4	98	18	47	29	42	.08	.08	0	1	0	16	0	0	NW.
September	75.4	45.2	60.3	88	24	29	29	44	.69	.44	0	8	0	0	2	0	NW.
October	62.6	33.8	48.0	89	7	12	25	51	.12	.12	T.	1	0	0	12	0	NW.
November	47.2	28.3	37.8	62	[1] 17	7	27	34	.50	.26	2.3	6	2	0	22	0	NW.
December	28.1	13.8	21.0	47	24	−24	13	26	.99	.34	8.0	6	17	0	30	5	NE.
Year	62.3	36.6	49.8	104	Jul 15	−24	Dec. 13	51	5.50	.44	21.4	54	29	38	147	5	NW.

1920.

Month.	Maximum.	Minimum.	Monthly.	Highest.	Date.	Lowest.	Date.	Greatest daily range.	Total.	Greatest in 24 hours.	Total snowfall (unmelted).	Precipitation (0.01 inch or more).	32° or below.	90° or above.	32° or below.	0° or below.	Prevailing direction of wind.
January	35.5	21.3	28.4	60	[1] 16	10	6	27	0.94	0.64	7.5	3	15	0	27	0	NW.
February	47.2	25.4	36.3	62	12	20	[1] 22	38	.04	.04	T.	1	0	0	28	0	NE.
March	58.2	29.6	43.9	68	12	16	17	42	.02	.02	T.	1	0	0	21	0	NW.
April	62.2	34.3	48.2	82	26	24	3	42	.53	.14	2.0	8	0	0	11	0	NW.
May	71.7	41.2	56.4	86	7	32	[1] 28	44	.39	.25	0	3	0	0	2	0	NW.
June	78.7	48.6	63.6	98	30	40	1	45	.33	.11	0	5	0	3	0	0	NW.
July	91.2	58.6	74.8	100	28	50	[1] 13	41	.25	.16	0	2	0	20	0	0	NW.
August	86.7	55.2	71.0	102	15	39	28	43	.44	.35	0	2	0	17	0	0	NW.
September	76.0	46.1	61.0	91	3	35	26	41	1.18	.32	0	6	0	3	0	0	NW.
October	62.4	37.2	49.8	78	4	26	20	33	.55	.30	0	4	0	0	10	0	NW.
November	49.4	28.8	39.1	59	7	14	10	35	1.35	.44	T.	7	0	0	25	0	W.
December	39.7	25.9	32.8	50	[1] 3	12	25	21	1.82	.34	9.8	10	3	0	29	0	NW.
Year	63.2	37.7	50.4	102	Aug. 15	10	Jan. 6	45	7.84	.64	19.3	52	18	43	153	0	NW.

1921.

Month.	Maximum.	Minimum.	Monthly.	Highest.	Date.	Lowest.	Date.	Greatest daily range.	Total.	Greatest in 24 hours.	Total snowfall (unmelted).	Precipitation (0.01 inch or more).	32° or below.	90° or above.	32° or below.	0° or below.	Prevailing direction of wind.
January	38.9	22.4	30.6	54	14	9	[1] 6	30	1.52	0.35	15.1	11	6	0	28	0	NE.
February	43.9	27.3	35.6	61	11	15	21	32	.59	.22	5.5	8	0	0	21	0	NW.
March	57.2	32.7	45.0	70	31	26	[1] 14	40	.25	.12	T.	4	0	0	18	0	NW.
April	63.4	36.2	49.8	76	11	26	24	38	.35	.18	T.	3	0	0	8	0	NW.
May	75.9	44.5	60.2	90	24	30	11	44	.92	.83	0	4	0	1	1	0	NW.
June	82.7	51.2	67.0	94	23	38	14	40	.27	.10	0	5	0	2	0	0	NW.
July	88.5	53.5	71.0	98	31	42	3	42	T.	T.	0	0	0	17	0	0	NW.
August	88.6	54.9	71.8	100	13	41	24	41	.02	.02	0	1	0	15	0	0	SW.
September	73.7	42.5	58.1	82	27	31	12	40	.27	.26	0	2	0	0	2	0	NW.
October	68.4	37.3	52.8	83	10	30	23	46	.31	.22	0	3	0	0	5	0	NE.
November	47.8	26.0	36.9	68	6	6	23	35	2.33	.85	5.4	7	5	0	23	0	NW.
December	37.3	24.0	30.8	66	12	6	31	26	1.24	.49	9.9	9	11	0	22	0	NW.
Year	63.9	37.7	50.8	100	Aug. 13	6	Nov. 23	46	8.07	.85	55.9	57	22	35	128	0	NW

[1] Occurring on more than one day.

NOTE.—Precipitation includes rain and melted snow, hail, and sleet. "T" indicates trace of precipitation.

DEFINITIONS OF TERMS.

The terms used in describing the various stages of the codling moth are the same as those employed by other members of the Bureau of Entomology in previous life-history studies.

A "generation" begins with the egg stage and ends with the adult or moth, and may or may not be completed the same season it begins.

A "brood" includes the individuals of any one of these stages, such as eggs, larvæ, pupæ, or adults, and may be spoken of as "first brood," "second brood," etc., to designate the generation to which it belongs. "Spring brood" includes the individual pupæ or adults which come from the "wintering larvæ," the latter being all the individuals of all the generations of the preceding season which do not complete their development until spring.

The time of cocooning is spoken of as the "cocooning period," since it is a part of the larval period.

The "life cycle" of any generation is the time from the deposition of the egg to the emergence of the adult.

The "complete life cycle" includes the time from the deposition of the egg of one generation to the deposition of the egg of the next generation.

The terms used in this bulletin may be defined as follows:

The *wintering larvæ* (*spring-brood larvæ*) include all of the non-transforming larvæ of the first, second, and third broods of the preceding season.

The *spring brood of pupæ* are the pupæ from the wintering larvæ.

The *spring brood of moths* are the moths emerging from the spring brood of pupæ.

The *first generation* includes:

- The first brood of eggs (deposited by spring-brood moths).
- The first brood of larvæ, both transforming and wintering.
- The first brood of pupæ.
- The first brood of moths.

The *second generation* includes:

- The second brood of eggs (deposited by first-brood moths).
- The second brood of larvæ, both transforming and wintering.
- The second brood of pupæ.
- The second brood of moths.

The *third generation* (not complete in Washington) includes:

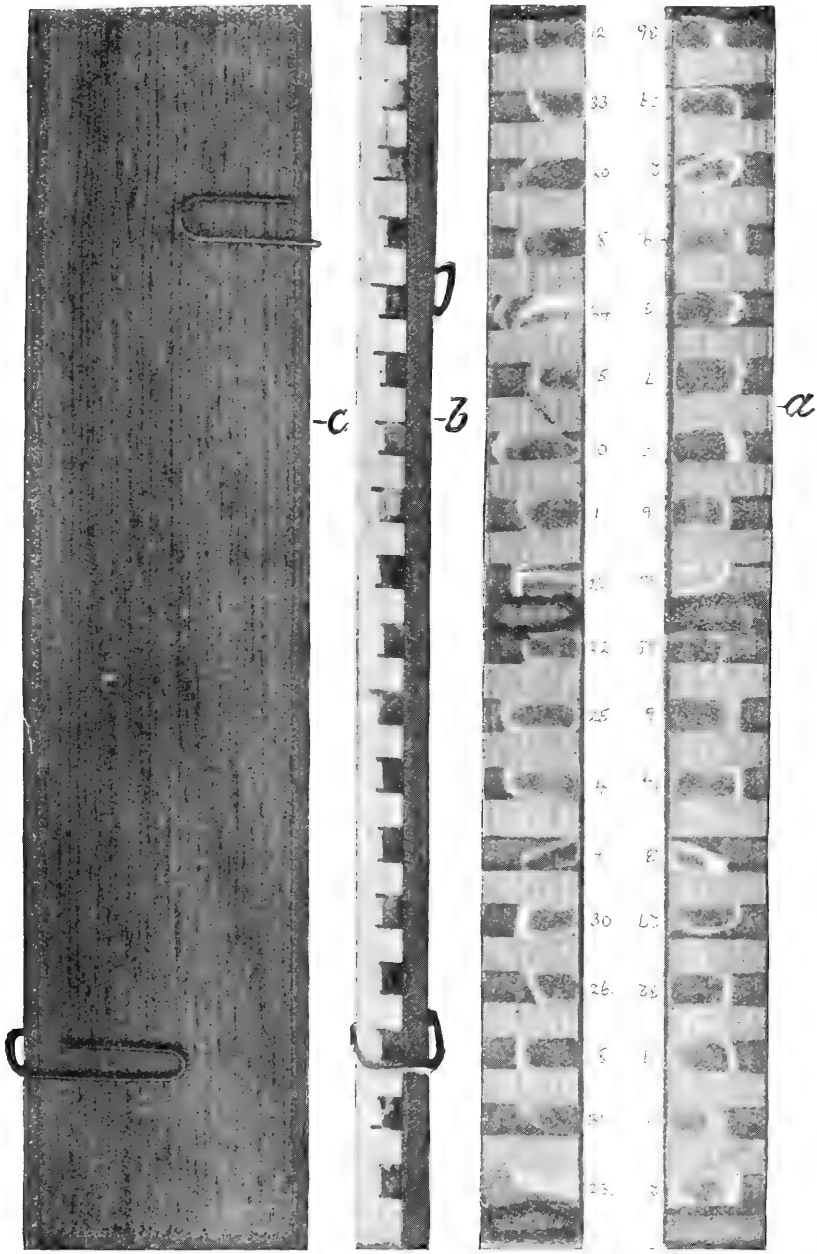
- The third brood of eggs (deposited by second-brood moths).
- The third brood of larvæ, all of which are wintering larvæ.

METHODS AND REARING APPARATUS EMPLOYED IN THE LIFE-HISTORY STUDIES.

The method of procedure followed in the life-history work in Yakima was similar to that followed in other investigations of the codling moth by the bureau, the object being to obtain data easily comparable to those from other sections of the country.

All of the rearing cages were glass battery jars, 6 by 8 inches, covered with coarsely woven cloth tops held in place by rubber bands and containing a layer of slightly moist sand in the bottom.

Pupation studies.—Wintering larvæ in the cells of cocooning racks were confined in the battery-jar cages and observed daily for the



THREE VIEWS OF COCOONING RACK: *a*, WITH COVER REMOVED TO SHOW THE COCOONING CELLS; *b*, SIDE VIEW; *c*, TOP VIEW

THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

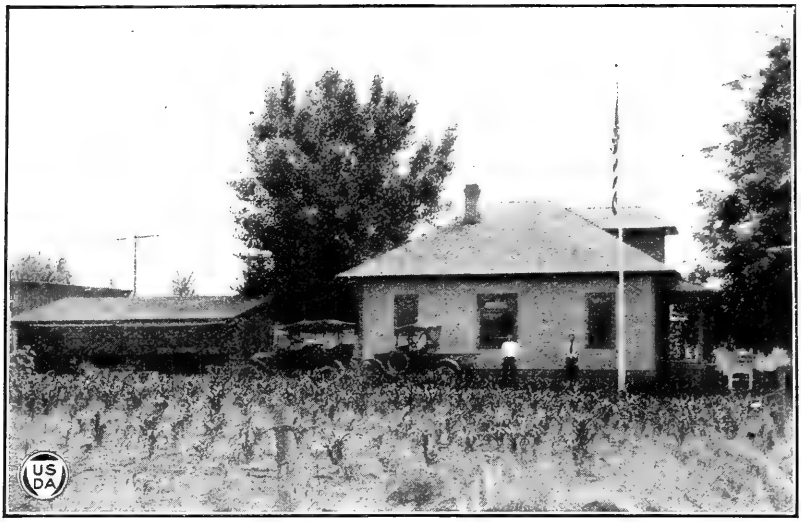


FIG. 1.—VIEW OF LABORATORY AND INSECTARY

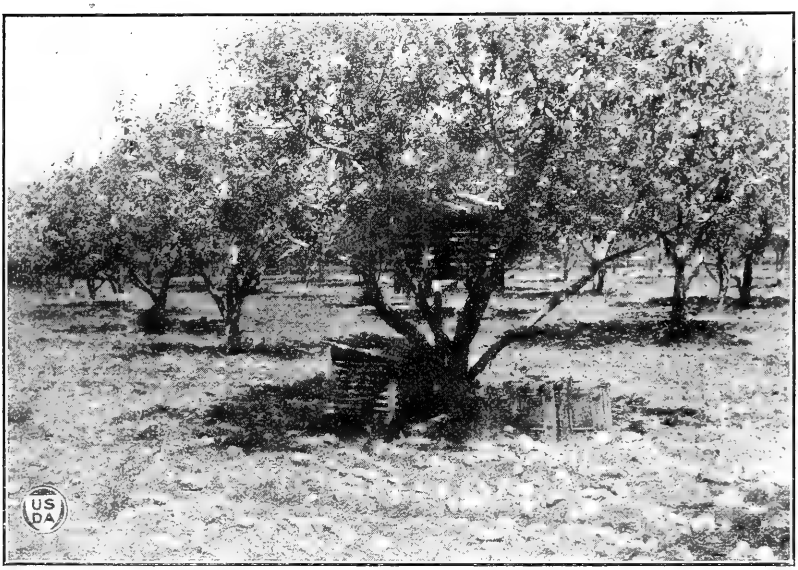


FIG. 2.—VIEW IN EXPERIMENTAL ORCHARD SHOWING SOIL CAGES, ONE BAND CAGE, AND SHELTERS FOR AIR AND SOIL THERMOGRAPHS

THE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

time of pupation. The cocooning rack (Pl. I) consists of a strip of soft wood 7¾ inches long, 1¾ inches wide, and one-fourth inch thick. On one side of this a central longitudinal groove is cut one-eighth inch deep and one-half inch wide. In this is glued a strip of hard wood, and on each side of it is a row of transverse cells extending to the edge of the rack, each cell being one-eighth inch wide and one-eighth inch deep. The hardwood strip prevents the larvæ from boring through to the cell on the opposite side. Each row of cells is covered with a strip of transparent celluloid, and a strip of paper is pasted to the hardwood, on which to record the number of each cell. The whole rack is covered with a thin strip of wood, held in place by wire paper clips.

Studies of the pupal period were made from the same cages as the pupation studies, the date of emergence of the moth being recorded daily.

Studies of moth emergence.—Each morning, before the heat of the day, moths emerging on the preceding day were counted and placed in oviposition jars.

Studies of oviposition.—Moths were confined in the regular battery-jar cages, in which were fresh pear leaves and a small sponge moistened in a solution of brown sugar. The number of moths in each cage was limited to about 25, those issuing each day being confined together, but separated from those issuing on other days. The leaves were removed daily, the eggs counted, the sponge remoistened, and fresh leaves put in the cage. No effort was made to control the number of male or female moths in each cage.

Studies of the length of life of the moths.—At the daily examination of the oviposition cages all dead moths were removed and their sex and length of life recorded.

Studies of the incubation period.—Leaves on which eggs had been deposited were placed between sheets of wire cloth in battery-jar cages to prevent them from curling. Daily observations to determine the appearance of the "red ring," which is probably the germ band, the "black spot," which is the black head and cervical shield of the young larva, and the time of hatching were made. These observations were made in the evening after the heat of the day. The number of eggs hatching was determined from the empty eggshells rather than from the number of young larvæ observed. Worm-free apples were placed in the incubation cages, in order that the worms might begin feeding immediately after hatching. These apples were removed daily and fresh apples substituted.

Studies of the larval feeding period.—Apples containing newly hatched larvæ from the incubation cages were placed in wire baskets in regular cages each day. At the end of 10 days, cocooning racks were placed in the cages and these examined daily, the number and date of larvæ leaving the fruit being recorded. This is called the "stock-jar feeding method." In the "bagged-fruit feeding method," newly hatched larvæ were placed on worm-free apples in the orchard and confined by well-ventilated paper sacks for 10 days, after which they were brought to the insectary and handled as in the stock-jar method.

THE INSECTARY.

Practically all of the life-history studies of the codling moth were made in the insectary, which was located in the rear of the laboratory (Pl. II, fig. 1). This was a frame structure 30 feet long by 12 feet wide, with a slanting roof dropping 40 inches to a minimum height of 8 feet. The sides were covered with wire screen, permitting a good circulation of air and preventing the escape of moths and the entrance of intruders. It was shaded and protected from the wind by several buildings, a large tree, and canvas awnings.

A thermograph and maximum and minimum thermometers in the insectary were used to compute the temperature records referred to in this bulletin in connection with the charts and diagrams. A thermograph operated in the orchard where the spraying experiments were conducted showed the temperatures there to have a lower maximum and a higher minimum, but showed that the monthly mean temperatures for the growing season were only 0.79° F. higher than those at the insectary. The climatological data given in Table 1 are taken from the records of the United States Weather Bureau station, which is about 3 miles from the insectary, and show the monthly mean temperatures of the same period to be higher by 4.1° F. The daily mean temperatures reported by the Weather Bureau are determined by averaging the maximum and minimum temperatures for the day. Those obtained in the insectary and orchard were computed by weighting the hourly readings recorded by the thermographs for the seasons of 1919 and 1920, while for 1921 the daily average temperatures were computed from the thermograph records for each two hours.

SEASONAL-HISTORY STUDIES OF 1919.

The seasonal-history studies of the codling moth were commenced in the spring of 1919 with observations on the pupation period of wintering larvæ. The season of 1919 began with approximately normal temperatures, but an abnormal drop occurred on May 29 and 30, the minimum temperature on the latter date being 32° F. The mean temperature for June was below normal, after which the weather was about normal for the rest of the fruit season. The rainfall was deficient, the year's total being 5.5 inches, or 1.79 inches below normal. Apple trees bloomed at Yakima April 25 to 30, and the calyx spray was applied about May 10.

The tables showing the seasonal history of the various stages should be considered separately, as, owing to accidents, natural mortality, or the removal of individuals for other reasons, it is not possible to carry all the individuals through all stages. The life-cycle tables, however, summarize the life history of those individuals which were reared from the egg to the adult stage

WINTERING LARVÆ.

Wintering larvæ construct heavy, closely woven cocoons, usually well hidden under pieces of loosened bark on the tree trunk, in the crotches of the tree, and in the soil at its base. When the weather begins to warm up in the spring the larva opens one end of the cocoon and forms a silken exit tube to the nearest place free from obstruction, through which the pupa wriggles when ready to disclose the moth.

Material for the seasonal-history studies of 1919 was obtained from banded apple trees in the vicinity of Yakima. The larvæ were collected early in March, before the exit tubes had been constructed, and were allowed to spin new cocoons in the cocooning racks.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—Daily examinations of the cocooning racks were made and the first pupa was found on March 30. No more pupated until April 8, and the last wintering larva pupated on May 30. The

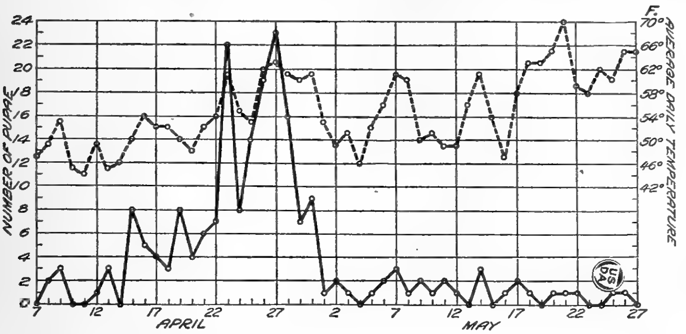


FIG. 1.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1919.

period of greatest pupation extended from April 15 to April 30, with a maximum April 27. The time of pupation of 201 individuals is illustrated in Figure 1.

Length of the pupal stage.—Table 2 gives the length of the pupal stage of 180 pupæ of the spring brood.

TABLE 2.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1919.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Mar. 30....	1	44.00	44	44	Apr. 29....	6	31.67	34	29
Apr. 8....	2	39.50	40	39	30....	5	32.60	34	31
9....	3	40.00	41	39	May 1....	1	32.00	32	32
12....	1	38.00	38	38	2....	1	32.00	32	32
13....	3	37.00	37	37	3....	1	32.00	32	32
15....	8	35.25	36	34	5....	1	29.00	29	29
16....	4	35.25	36	35	6....	2	29.00	30	28
17....	4	34.00	34	34	7....	3	29.33	30	29
18....	3	33.00	33	33	9....	2	27.00	27	27
19....	7	32.57	33	32	10....	1	28.00	28	28
20....	4	31.25	32	31	11....	2	26.50	28	25
21....	4	32.25	34	31	12....	1	30.00	30	30
22....	6	31.00	32	30	14....	3	29.33	30	29
23....	20	31.05	33	29	17....	2	29.50	33	26
24....	8	31.13	32	29	18....	1	31.00	31	31
25....	13	29.92	31	26	20....	1	27.00	27	27
26....	18	30.28	31	29	21....	1	28.00	28	28
27....	22	31.23	35	29	30....	1	27.00	27	27
28....	14	31.14	34	29					

Total number of pupæ....................	180
Average length of pupal period in days....................	31.63
Maximum length of pupal period in days....................	44
Minimum length of pupal period in days....................	25

MOTHS OF THE SPRING BROOD.

Time of emergence.—The first moth emerged May 13, about two weeks after the apple trees were in full bloom. Moths continued to emerge until June 19, as shown in Figure 2, with a final straggler on June 26. The maximum period of emergence occurred from May 18 to June 5, with a maximum of 85 moths on May 21. On May 29 and 30 there was a decided drop in the temperature, resulting in a temporary falling off of the number of moths emerging. Otherwise the emergence curve is fairly regular.

Oviposition by moths of the spring brood.—Oviposition records were obtained from 579 moths of the spring brood. One lot of moths, emerging May 27, began ovipositing the next day, but the interval before oviposition averaged 5.53 days, with a maximum of 18 days. The interval before maximum oviposition averaged 9.93 days, with an average oviposition period of 14.67 days and an average time from emergence to last oviposition of 19.2 days. All these data are given in Table 3. It must be borne in mind that these averages are for cages and not for individuals. Some individual averages will be found on page 67.

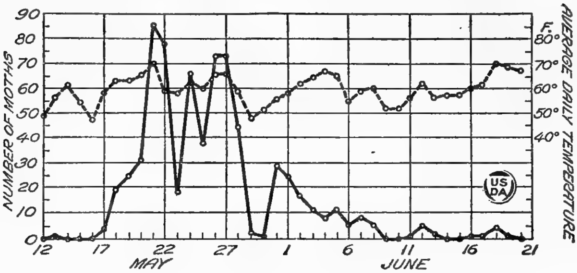


FIG. 2.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1919.

TABLE 3.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1919.*

Observation.	Number of moths.	Sex. Male.	Sex. Female.	Date of— Emergence.	Date of— First oviposition.	Date of— Maximum oviposition.	Date of— Last oviposition.	Number of days— Before oviposition.	Number of days— From emergence to maximum oviposition.	Number of days— Of oviposition.	Number of days— From emergence to last oviposition.	Total number of eggs deposited.
1	19	14	5	May 18	May 21	May 28	June 5	3	10	16	18	13
2	24	14	10	May 19	June 6	June 6	June 16	18	18	11	28	10
3	26	18	8	May 20	May 22	May 26	June 5	2	6	15	16	43
4	75	34	41	May 21	May 23	June 1	June 15	2	11	24	25	212
5	74	42	32	May 22	May 26	June 3	...do.....	4	12	21	24	202
6	18	9	9	May 23	May 31	June 6	June 16	8	14	17	24	40
7	50	18	32	May 24	May 26	June 4	...do.....	2	11	22	23	450
8	25	14	11	May 25	June 1	June 1	...do.....	7	7	16	22	157
9	74	35	39	May 26	...do.....	June 4	June 17	6	9	17	22	112
10	72	32	40	May 27	May 28	June 3	June 14	1	7	18	18	493
11	43	16	27	May 28	June 1	June 4	June 15	4	7	15	18	130
12	26	12	14	May 31	June 7	June 7	June 8	7	7	2	8	4
13	26	10	16	June 1	...do.....	June 16	June 16	6	15	10	15	21
14	17	8	9	June 2	June 12	June 14	...do.....	10	12	5	14	15
15	10	3	7	June 3	June 6	June 6	...do.....	3	3	11	13	5
Average								5.53	9.93	14.67	19.20	......
Maximum								18	18	24	28	......
Minimum								1	3	2	8	......

Number of male moths	279
Number of female moths	300
Total number of moths	579
Total number of eggs	1,907
Average number of eggs per female moth	6.36

Number of eggs per female.—The average number of eggs per female in the cages from which the data given in Table 3 were secured was 6.36, 300 females depositing a total of 1,907 eggs.

Length of life of moths.—Records of the length of life of 285 male moths and 300 females were obtained from the oviposition cages, and these are given in Table 4.

TABLE 4.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1919.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life	Number of moths.	Length of life.	Number of moths.
Days		*Days*		*Days.*		*Days.*		*Days.*		*Days.*	
1	1	1	0	12	10	12	7	23	12	23	13
2	2	2	4	13	16	13	18	24	4	24	6
3	5	3	1	14	13	14	8	25	9	25	8
4	12	4	3	15	16	15	19	26	15	26	8
5	9	5	3	16	18	16	16	27	8	27	9
6	7	6	7	17	14	17	27	28	5	28	2
7	12	7	5	18	12	18	18	29	0	29	1
8	11	8	9	19	5	19	19				
9	8	9	6	20	14	20	28	Total..	285	Total..	300
10	13	10	11	21	7	21	13				
11	10	11	8	22	17	22	23				

Average length of life of male moths, 15.33 days; female moths, 16.91 days.
Maximum length of life, male moths, 28 days; female moths, 29 days.
Minimum length of life, male moths, 1 day; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—Spring-brood moths in the insectary began ovipositing May 21, and with the exception of two days eggs were deposited every day until June 24. These two days were May 29 and 30, which were abnormally cold. The oviposition record is delineated in Figure 3. As shown on page 64, the majority of the eggs are deposited between 3 and 9 p. m. The average temperature for this 6-hour period is therefore given on the diagram, instead of the usual average daily temperature. A reference to Tables 52 and 53 will show also that as the temperature decreases the number of eggs deposited diminishes, until at 60° F. and lower it is rare for any eggs at all to be deposited. Figure 3 shows graphically how closely the number of eggs deposited follows the fluctuations in the temperature curve. The majority of the eggs of the first brood were deposited

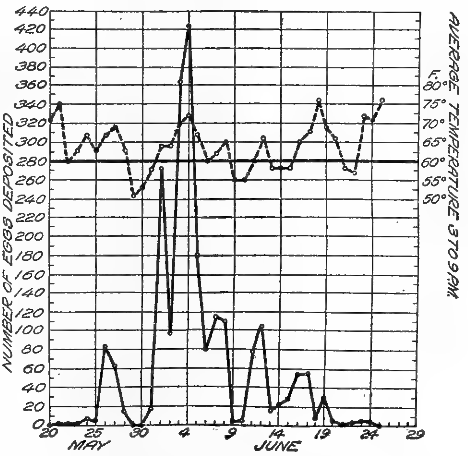


FIG. 3.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1919.

from June 1 to June 8, inclusive, with a maximum deposition of 422 eggs on June 4.

Length of incubation.—Incubation records of 837 eggs are given in Table 5. The earlier eggs required rather more than the average period for incubation, while later, when the temperature was higher, the average period was much reduced.

TABLE 5.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1919.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
May 26	35	5.00	5	5	11.00	11	11	12.91	14	12
27	10	3.00	3	3	9.00	9	9	11.30	12	11
June 1	61	3.00	3	3	10.61	11	9	12.65	14	12
2	38	3.00	3	3	10.00	10	10	12.00	12	12
3	161	3.00	3	3	10.21	11	10	13.02	14	12
4	218	5.00	5	5	10.14	11	10	13.96	15	13
5	76	5.00	5	5	12.67	13	12	14.47	16	14
6	34	6.00	6	6	12.00	12	12	13.29	14	13
7	33	7.00	7	7	10.00	10	10	13.18	14	13
8	45	8.00	8	8	10.00	10	10	12.51	13	12
9	2	8.00	8	8	10.00	10	10	11.50	12	11
11	14	7.00	7	7	9.00	9	9	10.43	11	10
12	36	7.00	7	7	9.00	9	9	10.28	11	10
13	10	7.00	7	7	8.00	8	8	9.90	11	9
14	10	6.00	6	6	8.00	8	8	9.30	10	9
15	6	6.00	6	6	7.00	7	7	9.00	9	9
16	3	6.00	6	6	8.00	8	8	9.00	9	9
17	39	6.00	6	6	7.00	7	7	8.05	9	8
18	1	5.00	5	5	7.00	7	7	8.00	8	8
20	2	4.00	4	4	7.00	7	7	9.00	9	9
23	3	3.00	3	3	5.00	5	5	6.00	6	6
	837	4.85	8	3	10.17	13	5	12.73	16	6

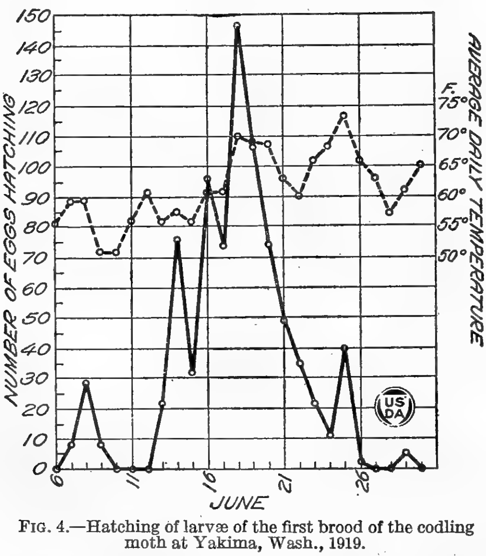


FIG. 4.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1919.

LARVÆ OF THE FIRST BROOD.

Time of hatching.—First-brood larvæ began hatching in the insectary on June 7 (fig. 4), and continued until June 29, a total period of 23 days. On June 10, 11, and 12, no larvæ hatched, owing not so much to low temperatures at this time as to the fact that no eggs were deposited on May 29 and 30. The majority of larvæ hatched from June 16 to 20, inclusive, the maximum of 147 occurring on June 18, 11 days after the first larva hatched.

Length of the feeding period, stock-jar method.—Table 6 gives the length of the feeding period of 135 first-brood larvæ (both transforming and nontransforming) in stock jars (see p. 5).

TABLE 6.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 14	6	25.67	28	24	June 22	5	25.60	29	23
16	12	25.34	28	21	23	6	22.50	24	21
18	26	24.15	33	20	24	2	22.50	23	22
19	23	24.17	32	19	25	16	21.63	25	18
20	18	23.78	30	20	26	1	30.00	30	30
21	18	23.50	33	20	28	2	19.50	21	18

Total number of larvæ 135
Average length of feeding period in days 23.82
Maximum length of feeding period in days 33
Minimum length of feeding period in days 18

Length of the feeding period, bagged-fruit method.—The length of the feeding period of 70 larvæ (both transforming and nontransforming) reared by the bagged-fruit method (see p. 5) is given in Table 7. Larvæ reared by this method occupied a slightly longer time in feeding than where reared by the stock-jar method.

TABLE 7.—*Length of feeding period of larvæ of the first brood of the codling moth, bagged-fruit method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 7	3	25.00	26	24	June 18	3	25.00	27	24
9	2	33.50	39	28	19	6	21.17	24	18
12	3	24.33	26	22	20	15	25.33	33	22
13	6	27.50	29	25	21	5	23.40	26	21
16	10	24.20	27	22	23	6	24.00	27	21
17	6	24.50	28	22	24	5	25.00	29	22

Total number of larvæ 70
Average length of feeding period in days 24.81
Maximum length of feeding period in days 39
Minimum length of feeding period in days 18

Length of the cocooning period.—The cocooning period represents the total time elapsing from the date the larva leaves the fruit until it pupates, although the actual period of constructing the cocoon is necessarily somewhat shorter. In Table 8 will be found data showing the cocooning period of 146 transforming individuals of the first brood.

TABLE 8.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1919.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 1	1	6.00	6	6	July 14	17	9.59	28	4
2	1	6.00	6	6	15	22	8.36	26	3
3	1	5.00	5	5	16	12	7.25	26	5
4	1	4.00	4	4	17	3	10.33	21	4
7	1	5.00	5	5	18	3	4.67	6	4
8	9	4.56	5	4	19	6	6.67	15	4
9	8	5.25	9	4	20	2	11.00	16	6
10	10	4.80	5	4	21	1	15.00	15	15
11	11	4.91	8	4	23	1	6.00	6	6
12	21	6.81	25	4	24	1	6.00	6	6
13	14	7.07	21	4					
						146	6.99	28	3

PUPÆ OF THE FIRST BROOD.

Time of pupation.—Transforming larvæ of the first brood began pupating July 7, and continued until August 12, the largest number pupating from July 13 to 23, with the maximum July 19. (See Fig. 5.)

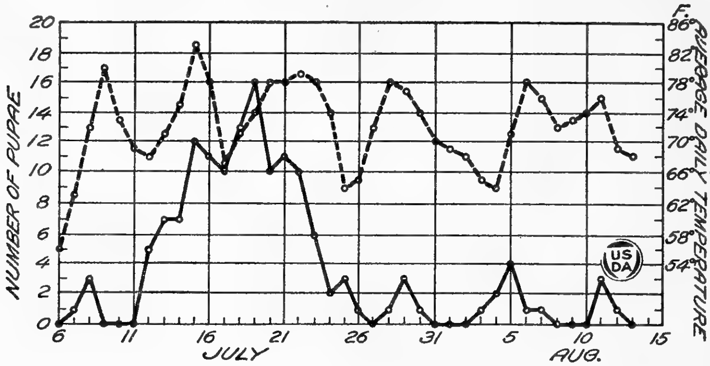


FIG. 5.—Pupation of the first brood of the codling moth at Yakima, Wash., 1919.

Length of pupal stage.—Data on the length of the pupal stage of the first brood of pupæ were secured from 128 individuals, as indicated in Table 9.

TABLE 9.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1919.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 7	1	12.00	12	12	July 23	6	14.00	17	9
8	2	11.50	12	11	24	1	13.00	13	13
12	4	11.00	12	10	25	3	13.33	14	12
13	7	12.43	14	10	26	1	15.00	15	15
14	5	12.60	13	11	28	1	14.00	14	14
15	11	12.55	15	11	29	3	15.33	16	15
16	9	12.22	13	11	30	1	13.00	13	13
17	9	12.11	13	11	Aug. 3	1	14.00	14	14
18	12	13.42	21	12	4	2	13.50	14	13
19	13	17.31	44	11	5	4	13.25	14	13
20	9	12.89	15	10	6	1	15.00	15	15
21	11	16.27	44	10	7	1	12.00	12	12
22	8	17.75	37	13	11	2	13.00	14	12

Total number of pupæ........ 128
Average length of the pupal stage in days........ 13.91
Maximum length of the pupal stage in days........ 44
Minimum length of the pupal stage in days........ 9

MOTHS OF THE FIRST BROOD.

Time of emergence.—Figure 6 combines the records of emergence of the first brood of moths from insectary-bred material and from band-record material. The first moth emerged July 8, the last, September 24, and the maximum number, July 19. From the insectary-bred material, the first moth was secured July 19, the last September 3, and the maximum July 30. Some, if not most, of the moths emerging in September from the band-record material were probably second-brood moths, as several second-brood moths emerged from the insectary-bred material at this time. There is some overlapping, as evidenced by the fact that the first moth of the second

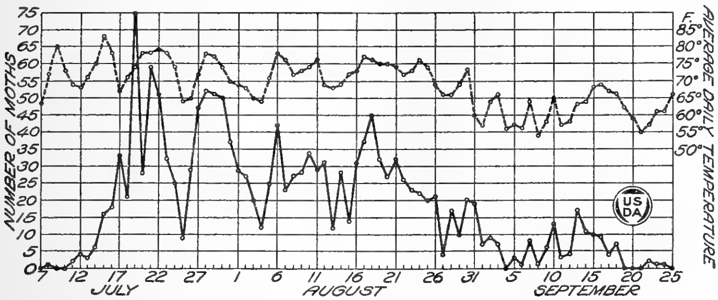


FIG. 6.—Emergence of the first and second broods of moths of the codling moth at Yakima, Wash., 1919.

brood emerged August 29, while the last of the first brood emerged September 3. For this reason, and because the second brood is quite small, the records of the two have been combined.

Oviposition by moths of the first brood.—As the spraying schedule in the Yakima Valley requires an application of spray for the earliest worms of the second brood, it is important to obtain the earliest date of oviposition. On account of this, moths emerging from the band-record material collected in the field were used for obtaining oviposition records, as the larvæ from which they were reared had been under natural conditions. A total of 1,251 moths were used. In most cases these moths began ovipositing the day following their emergence. (See Table 10.) The averages are for cages and not individuals. For some individual averages see page 69.

TABLE 10.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1919.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	18	7	11	July 16	July 18	July 21	Aug. 4	2	5	18	19	167
2	32	17	15	July 17	...do.....	July 20	July 26	1	3	9	9	196
3	21	10	11	July 18	July 20	...do.....	Aug. 3	2	2	15	16	144
4	74	40	34	July 19	...do.....	...do.....	Aug. 7	1	1	19	19	923
5	25	10	15	July 20	July 21	July 21	Aug. 3	1	1	14	14	406
6	58	25	33	July 21	July 22	July 23	Aug. 9	1	2	19	19	481
7	46	23	23	July 22	July 23	July 29	Aug. 5	1	7	14	14	237
8	20	11	9	July 23	July 26	July 30	Aug. 3	3	7	9	11	108
9	23	14	9	July 24	...do.....	July 29	Aug. 9	2	5	15	16	209
10	29	14	15	July 26	July 29	Aug. 1	Aug. 6	3	6	9	11	248
11	33	10	23	July 27	July 28	July 29	Aug. 9	1	2	13	13	657
12	36	11	25	July 28	July 29	...do.....	...do.....	1	1	12	12	720
13	36	11	25	July 29	July 30	July 31	Aug. 11	1	2	13	13	930
14	50	27	23	July 30	July 31	Aug. 7	Aug. 19	1	8	20	20	667
15	30	15	15	July 31	Aug. 2	Aug. 5	Aug. 18	2	5	17	18	291
16	19	10	9	Aug. 1	...do.....	...do.....	Aug. 10	1	4	9	9	376
17	27	16	11	Aug. 2	Aug. 5	...do.....	Aug. 14	3	3	10	12	129
18	21	7	14	Aug. 3	Aug. 6	Aug. 6	Aug. 21	3	3	16	18	356
19	25	11	14	Aug. 5	...do.....	Aug. 9	Aug. 15	1	4	10	10	750
20	40	17	23	Aug. 6	Aug. 7	Aug. 7	Aug. 24	1	1	18	18	249
21	22	10	12	Aug. 7	Aug. 8	Aug. 10	Aug. 11	1	3	4	4	66
22	27	13	14	Aug. 8	Aug. 9	Aug. 9	Aug. 18	1	1	10	10	465
23	28	9	19	Aug. 9	Aug. 12	Aug. 12	Sept. 4	3	3	24	26	254
24	31	15	16	Aug. 10	Aug. 11	Aug. 14	Aug. 21	1	4	11	11	508
25	27	6	21	Aug. 11	Aug. 14	Aug. 18	Aug. 29	3	7	16	18	229
26	33	13	20	Aug. 12	...do.....	...do.....	Aug. 25	2	6	12	13	543
27	27	11	16	Aug. 14	Aug. 15	Aug. 15	Aug. 27	1	1	13	13	179
28	14	6	8	Aug. 15	Aug. 17	Aug. 18	Aug. 25	2	3	9	10	211
29	30	9	21	Aug. 16	Aug. 18	Aug. 20	Sept. 3	2	4	17	18	610
30	37	18	19	Aug. 17	...do.....	...do.....	Sept. 2	1	3	16	16	207
31	45	19	26	Aug. 18	Aug. 19	Aug. 21	Aug. 31	1	3	13	13	585
32	32	16	16	Aug. 19	Aug. 20	Aug. 20	Sept. 10	1	1	22	22	448
33	27	12	15	Aug. 20	Aug. 21	Aug. 23	Sept. 4	1	3	15	15	396
34	32	12	20	Aug. 21	Aug. 22	Aug. 25	Sept. 10	1	4	20	20	480
35	26	11	15	Aug. 22	Aug. 23	Sept. 2	Sept. 13	1	11	22	22	338
36	22	10	12	Aug. 23	Aug. 24	Aug. 25	...do.....	1	2	21	21	315
37	21	8	13	Aug. 24	Aug. 25	Aug. 28	Sept. 10	1	4	17	17	190
38	21	12	9	Aug. 25	Aug. 26	Aug. 30	Sept. 13	1	5	19	19	286
39	21	9	12	Aug. 26	Aug. 28	...do.....	...do.....	2	4	17	18	320
40	16	5	11	Aug. 28	Sept. 1	Sept. 2	Sept. 16	4	5	16	19	685
41	10	4	6	Aug. 29	...do.....	Sept. 7	Sept. 13	3	9	13	15	228
42	20	10	10	Aug. 30	Sept. 2	Sept. 13	Sept. 18	3	14	17	19	216
43	19	11	8	Aug. 31	Sept. 1	Sept. 9	Sept. 20	1	9	20	20	276
	Average							1.63	4.21	14.95	15.58	......
	Maximum							4	14	24	26	......
	Minimum							1	1	4	4	......

Number of male moths	555
Number of female moths	696
Total number of moths	1,251
Total number of eggs	16,279
Average number of eggs per female moths	23.39

Number of eggs per female moth.—Table 10 shows that 696 female moths deposited 16,279 eggs, or an average of 23.39 eggs per female.

Length of life of moths.—Table 11 shows that of 555 male moths and 694 female moths, the males lived slightly longer.

TABLE 11.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1919.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	0	1	2	15	21	15	40	29	8	29	1
2	2	2	3	16	21	16	33	30	1	30	1
3	5	3	4	17	23	17	24	31	3	31	2
4	10	4	4	18	24	18	27	32	1	32	0
5	6	5	9	19	20	19	15	33	1	33	1
6	26	6	17	20	19	20	15	34	3	34	0
7	42	7	39	21	15	21	19	36	0	36	1
8	41	8	56	22	13	22	15	37	0	37	1
9	45	9	66	23	8	23	7	38	1	38	0
10	40	10	73	24	8	24	11	39	2	39	0
11	26	11	62	25	9	25	9	44	1	44	0
12	32	12	55	26	6	26	6	45	1	45	0
13	35	13	40	27	7	27	4				
14	26	14	27	28	3	28	5	Total.	555	Total.	694

Average length of life of male moths, 13.97 days; female moths, 13.09 days.
Maximum length of life of male moths, 45 days; female moths, 37 days.
Minimum length of life of male moths, 2 days; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life cycle, stock-jar feeding method.—Table 12 gives the life cycle of 78 individuals of the first generation, all of which were reared from egg to moth, the larvæ being fed by the stock-jar method. The incubation period averaged 12.18 days, larval feeding period 23.59 days, cocooning period 7.69 days, pupal period 13.33 days; a total of 56.79 days for the life cycle. In order to arrive at the complete life cycle from deposition of first-brood egg to deposition of second-brood egg 1.63 days should be added, which is the average interval between emergence of the first-brood moth and egg deposition. This gives a complete cycle of 58.42 days.

TABLE 12.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1919.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
June 2	5	12	25.40	28	24	8.60	25	4	13.00	15	11	59.00	80	51
3	6	13	25.83	28	22	6.50	11	4	12.83	16	10	58.16	64	53
4	12	14	24.08	31	21	6.83	15	5	13.50	15	12	58.41	74	53
5	7	14	23.86	32	19	13.00	21	4	12.14	14	10	63.00	74	48
7	14	13	24.07	30	20	7.28	19	4	14.42	37	11	58.77	82	49
8	15	13	23.07	33	20	6.67	28	4	13.27	15	10	56.01	78	49
12	2	10	23.50	24	23	5.50	6	5	13.00	13	13	52.00	52	52
12	4	11	22.50	24	21	14.25	26	5	12.00	12	12	59.75	72	49
15	1	9	23.00	23	23	6.00	6	6	14.00	14	14	52.00	52	52
17	11	8	21.91	24	18	5.82	10	4	13.64	15	9	49.37	53	45
20	1	8	18.00	18	18	5.00	5	5	12.00	12	12	43.00	43	43
	78	12.18	23.59	33	18	7.69	28	4	13.33	37	9	56.79	82	43

[1] Add 1.63 days for complete life cycle.

Life cycle, bagged-fruit feeding method.—In Table 13 are shown the life-cycle figures for 48 individuals of the first generation, the larvæ of which were fed by the bagged-fruit method.

TABLE 13.—*Life cycle of the first generation of the codling moth as observed by rearing, bagged-fruit feeding method, Yakima, Wash., 1919.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 26	2	12	25.00	26	24	5.50	6	5	12.00	12	12	54.50	55	54
June 1	3	11	24.33	26	22	4.67	5	4	11.67	13	11	51.67	55	48
1	3	12	26.67	28	25	4.67	5	4	12.33	13	12	55.67	58	53
3	5	13	24.00	26	22	4.60	6	4	12.60	14	10	54.20	59	49
3	4	14	23.50	25	22	5.00	6	4	13.00	14	12	55.50	57	54
4	2	14	25.50	27	24	5.00	6	4	13.00	13	13	57.50	60	55
5	6	14	23.17	26	20	5.33	6	4	17.83	44	11	60.33	88	50
8	11	12	24.55	30	22	5.36	7	5	13.73	19	11	55.64	63	50
8	3	13	22.67	24	21	4.00	5	3	11.67	12	11	51.34	52	50
12	5	11	23.40	27	21	5.20	6	5	12.40	14	11	52.00	57	48
15	4	9	25.25	29	22	4.75	6	4	22.25	44	13	61.25	80	51
	48	12.25	24.23	30	20	5.00	7	3	14.19	44	10	55.67	88	48

[1] Add 1.63 days for complete life cycle.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The first eggs of the second brood were deposited by first-brood moths on July 15, and eggs were deposited

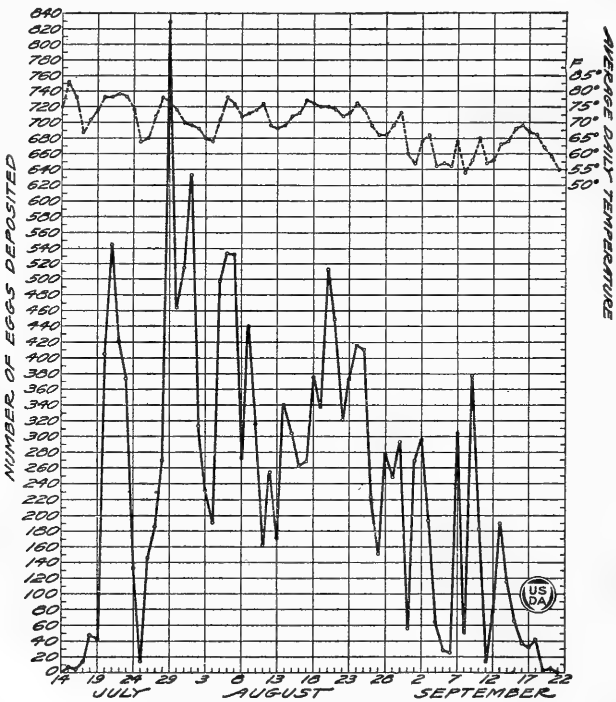


FIG. 7.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1919.

daily until September 20, as shown in Figure 7. The maximum period of oviposition is less decided and much longer than that of the spring brood of moths (see p. 9). It extended from the latter part of July until nearly the last of August, with an actual maximum of 829 eggs on July 29.

Length of incubation.—Data on this phase of the life history are set forth in Table 14. The average incubation period of 8.72 days is not much more than half that of the first brood of eggs.

TABLE 14.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1919.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
July 15	3	3.00	3	3	6.00	6	6	7.00	7	7
17	4	2.00	2	2	5.00	5	5	7.00	7	7
18	27	2.00	2	2	6.00	6	6	7.22	8	7
19	8	3.00	3	3	5.00	5	5	6.63	7	6
20	52	2.00	2	2	5.48	6	5	7.48	8	7
21	118	2.00	2	2	6.00	6	6	7.25	8	7
22	162	2.00	2	2	6.00	6	6	7.10	8	7
23	99	2.00	2	2	6.00	6	6	7.04	8	7
24	44	2.00	2	2	6.00	6	6	7.55	9	7
26	90	2.00	2	2	6.00	6	6	7.62	8	7
27	106	2.00	2	2	6.00	6	6	7.66	8	7
28	76	2.00	2	2	6.28	7	6	8.28	9	8
29	359	2.00	2	2	7.27	8	7	8.53	10	8
30	213	2.00	2	2	7.00	7	7	8.13	9	8
31	261	2.00	2	2	7.00	7	7	8.17	9	8
Aug. 1	231	3.00	3	3	7.00	7	7	8.26	9	8
2	135	2.00	2	2	7.00	7	7	8.01	9	8
3	77	2.00	2	2	7.00	7	7	8.34	9	8
4	102	2.00	2	2	6.00	6	6	7.16	8	7
5	201	2.00	2	2	6.00	6	6	7.19	8	7
6	151	2.00	2	2	6.00	6	6	7.00	7	7
7	130	2.00	2	2	6.00	6	6	7.60	9	7
8	59	2.00	2	2	6.00	6	6	7.90	8	7
9	120	2.00	2	2	6.00	6	6	7.04	8	7
10	115	2.00	2	2	6.00	6	6	7.22	8	7
12	64	2.00	2	2	6.00	6	6	7.00	7	7
13	91	2.00	2	2	6.00	6	6	7.08	8	7
14	108	2.00	2	2	6.00	6	6	7.03	8	7
15	56	2.00	2	2	6.00	6	6	7.07	8	7
16	104	2.00	2	2	6.00	6	6	7.02	8	7
17	59	2.00	2	2	6.00	6	6	7.10	8	7
18	31	2.00	2	2	6.00	6	6	7.16	8	7
19	28	2.00	2	2	6.00	6	6	7.07	8	7
20	58	2.00	2	2	6.00	6	6	7.12	8	7
21	158	2.00	2	2	6.00	6	6	7.72	8	7
22	52	2.00	2	2	6.94	7	6	8.06	9	7
23	100	2.00	2	2	7.00	7	7	8.05	9	8
24	94	2.00	2	2	7.00	7	7	9.27	10	9
25	101	2.00	2	2	8.00	8	8	10.19	12	10
26	36	2.00	2	2	9.00	9	9	12.50	14	12
27	22	2.86	3	2	10.86	11	10	12.05	13	11
29	158	2.00	2	2	10.85	13	10	12.61	15	11
30	109	2.00	2	2	13.00	13	13	15.49	17	14
31	14	1.00	1	1	14.00	14	14	15.71	17	15
Sept. 1	29	2.00	2	2	14.00	14	14	15.66	17	15
2	103	2.00	2	2	14.00	14	14	16.29	17	15
3	54	4.00	4	4	13.00	13	13	14.00	14	14
4	18	5.00	5	5	12.00	12	12	13.33	14	13
7	109	5.00	5	5	9.00	9	9	10.41	11	10
9	117	4.00	4	4	9.00	9	9	10.71	12	10
10	86	4.00	4	4	9.00	9	9	11.26	12	11
13	105	3.00	3	3	8.00	8	8	10.92	12	9
14	52	3.00	3	3	9.00	9	9	11.06	12	10
15	20	4.00	4	4	9.00	9	9	11.10	12	10
	5,079	2.26	5	1	7.29	14	5	8.72	17	6

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LARVÆ OF THE SECOND BROOD.

Time of hatching.—Second-brood larvæ were hatching for more than two months, beginning July 22, reaching a maximum August 7 and continuing until September 27. A reference to Figure 8 will show that the maximum period of hatching was much more prolonged than was the case with the first brood of larvæ.

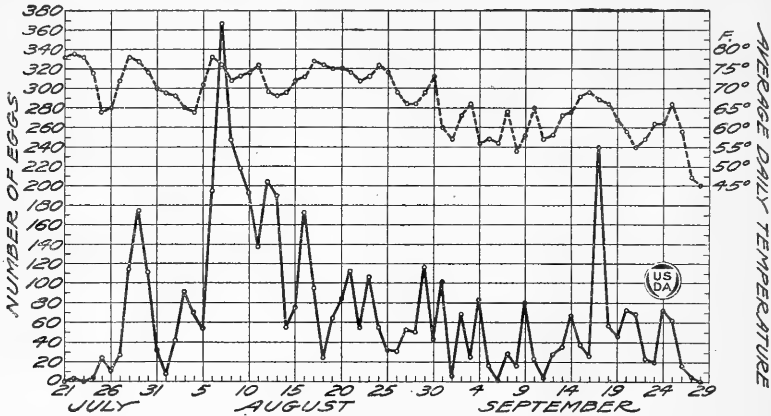

FIG. 8.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1919.

Length of feeding period, stock-jar method.—Table 15 shows data of 327 larvæ of the second brood, reared by the stock-jar method.

TABLE 15.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 22	3	26.00	32	22	Aug. 14	7	24.71	26	22
25	4	37.25	69	26	15	16	32.81	66	20
27	2	30.00	38	22	16	10	39.90	67	31
28	7	39.29	53	23	17	12	34.50	56	27
29	13	29.08	56	21	19	3	39.00	46	35
30	13	28.85	43	22	20	6	37.00	53	15
Aug. 1	5	28.20	36	23	21	5	44.60	52	36
2	8	29.00	39	22	22	4	52.50	57	47
3	4	26.50	28	24	23	5	44.20	60	27
4	4	30.50	38	25	24	2	47.00	47	47
5	8	29.63	43	19	25	2	49.50	56	43
6	12	34.75	61	23	26	2	59.00	63	55
7	37	29.62	40	20	27	4	44.75	54	38
8	36	33.75	57	19	28	4	54.00	61	49
9	16	38.31	62	22	30	1	51.00	51	51
10	15	37.67	46	28	31	1	52.00	52	52
11	12	35.58	56	19	Sept. 4	1	22.00	22	22
12	21	34.81	51	16	7	1	39.00	39	39
13	21	33.10	50	21					

Total number of larvæ	327
Average length of feeding period in days	34.51
Maximum length of feeding period in days	69
Mininum length of feeding period in days	15

Length of feeding period, bagged-fruit method.—In Table 16 it will be found that 93 larvæ reared by the bagged-fruit method fed an average of 29.75 days. The reason this average is less than that of the stock-jar larvæ is that this method was used only for larvæ entering the fruit for a period of two weeks, and during the time they were feeding the temperature averaged warmer than it did for the whole period of feeding of the second brood, which is covered by the stock-jar larvæ.

TABLE 16.—*Length of feeding period of larvæ of the second brood of the codling moth, bagged-fruit method, Yakima, Wash., 1919.*

Date of entering fruit.	Number of larvæ.	Feeding period in days. Average.	Maximum.	Minimum.	Date of entering fruit.	Number of larvæ.	Feeding period in days. Average.	Maximum.	Minimum.
July 26	5	28.00	34	25	Aug. 3	6	29.00	44	22
27	6	28.83	43	23	4	8	27.38	39	17
28	4	31.00	42	21	5	6	30.67	42	22
29	9	24.89	33	21	6	7	29.86	49	22
30	8	27.75	37	21	7	7	35.29	45	22
31	9	24.78	29	22	9	14	34.71	40	24
Aug. 2	4	35.50	43	27					

Total number of larvæ	93
Average length of feeding period in days	29.75
Maximum length of feeding period in days	49
Minimum length of feeding period in days	17

Length of the cocooning period.—Only five larvæ of the second brood pupated, all of them being among the earliest to leave the fruit. The cocooning period of these larvæ was 5, 6, 7, 9, and 9 days, respectively, the average being 7.20 days.

PUPÆ OF THE SECOND BROOD.

Time of pupation.—One larva pupated on August 18, one on August 26, and three on August 28.

Length of the pupal stage.—The pupal stage of these five individuals was 11, 14, 16, 19, and 20 days, respectively, the average being 16 days.

MOTHS OF THE SECOND BROOD.

Time of emergence.—The five pupæ mentioned above produced moths on August 29, September 11, 13, 15, and 16.

LIFE CYCLE OF THE SECOND GENERATION.

The life cycle of five individuals of the second generation is given in Table 17 and averages 52.2 days, which is somewhat shorter than that of the first generation.

TABLE 17.—*Life cycle of the second generation of the codling moth, as observed by rearing, Yakima, Wash., 1919.*

Egg deposition.	Hatching.	Date of— Larvæ leaving fruit.	Pupation.	Emergence of moths.	Days required for— Incubation.	Feeding of larvæ.	Cocooning.	Pupal period.	Life cycle.
July 15	July 22	Aug. 13	Aug. 18	Aug. 29	7	22	5	11	45
July 18	July 25	Aug. 20	Aug. 26	Sept. 15	7	26	6	20	59
July 20	July 27	Aug. 19	Aug. 28	Sept. 11	7	23	9	14	53
July 22	July 29	...do...	...do...	Sept. 13	7	21	9	16	53
July 27	Aug. 4	Aug. 21	...do...	Sept. 16	8	17	7	19	51
Average					7.2	21.8	7.2	16.0	52.2
Maximum					8	26	9	20	59
Minimum					7	17	5	11	45

THE THIRD GENERATION.

No attempt was made to secure eggs from the few second-brood moths that were reared. Hence no data are available for the third generation.

CODLING-MOTH BAND STUDIES OF 1919.

Owing to the fact that the Yakima Valley is divided into two parts it was considered advisable to keep band records in one orchard in the upper valley and one in the lower valley. The first orchard was inside the city limits of Yakima, about one-fourth mile from the laboratory, and will be spoken of as the Guthrie orchard. In the lower valley an orchard known as the Walden orchard was selected for banding. This is situated about a mile east of Buena and is at the western edge of a large apple district. It is approximately 15 miles southeast of Yakima.

In both orchards burlap bands made of strips of burlap 18 inches wide folded to three thicknesses were applied to the trunks of certain trees and held in place with wire finishing nails. The loose bark had previously been thoroughly scraped from the trees. These bands were examined every three days throughout the season, and the worms found were counted and put into glass jars, where they were

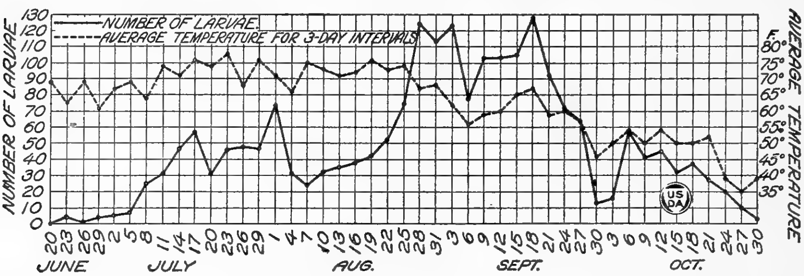

FIG. 9.—Occurrence of codling moth larvæ under bands of apple trees at Yakima, Wash., 1919.

allowed to spin cocoons in strips of corrugated pasteboard, the moths emerging from these cocoons being used in subsequent life-history studies.

In the Guthrie orchard the trees were large, being 25 years old or older. These trees were sprayed, but not efficiently enough to control the worms. Twenty-four trees were banded, and a total of 2,162 larvæ were collected. In Figure 9 will be found the details of these band collections. A distinct break between the first and second broods will be noted, occurring during the first week in August. The maximum for the first brood was 74 larvæ collected on August 1, but it is believed that the true maximum is more nearly represented by the high point of July 17, since the maximum number of larvæ left the fruit in the insectary on July 12. The maximum period of leaving fruit for the second brood occurred August 28 to September 3, and was September 3 at the insectary. A second high point occurred September 18. This was caused by the cool weather of September 3 to 12 slowing up the growth of the larvæ. As soon as the weather became warm again they left the fruit in large numbers.

The trees in the Walden orchard at Buena were 25 years old. Ten trees were banded, seven of them being sprayed and three unsprayed. A total of 5,044 worms was collected from these bands, 2,021 being from the seven sprayed trees and 3,023 from the three

unsprayed trees. The spraying of the trees greatly reduced the total number of worms but had no effect on the time of leaving fruit, the maximum number occurring in both groups of trees on the same day,

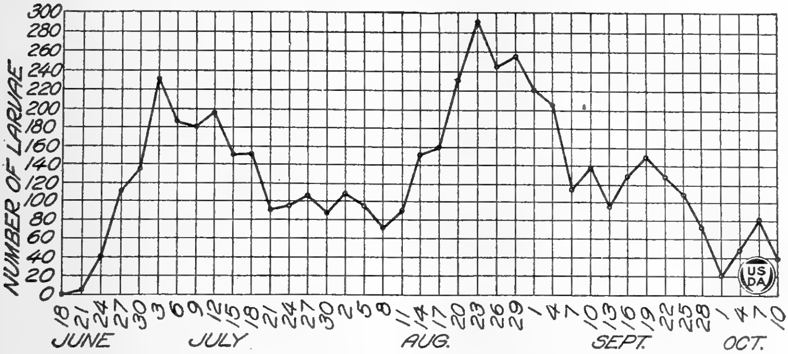

FIG. 10.—Occurrence of codling moth larvæ under bands on apple trees at Buena, Wash., 1919.

August 23. Here, as at Yakima, a definite break occurred between the first and second broods about the 1st of August (fig. 10). The maximum number of first-brood larvæ was collected on July 3, 14

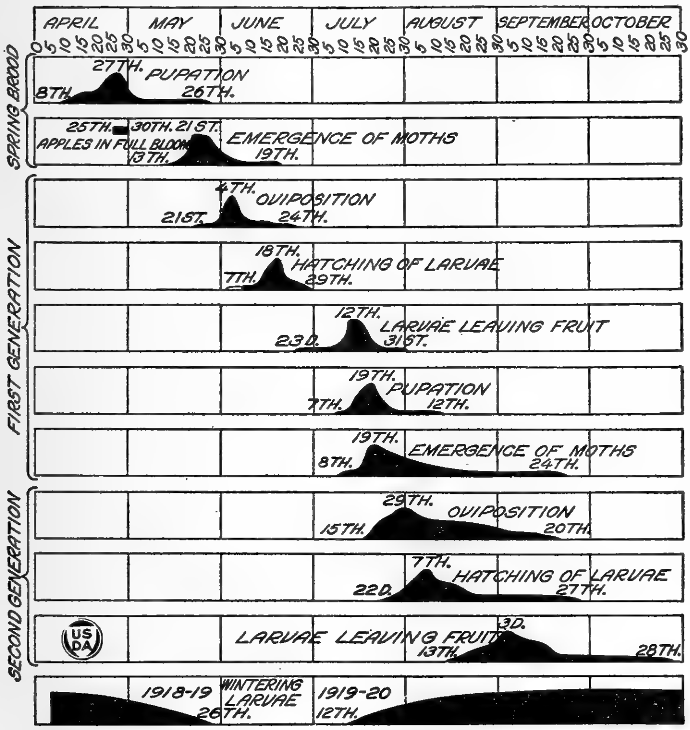

FIG. 11.—Seasonal history of the codling moth at Yakima, Wash., 1919.

days earlier than at Yakima, and the maximum number of second-brood larvæ occurred August 23, five days earlier than at Yakima.

A summary of the seasonal history of the codling moth in 1919 is shown in Figure 11.

SEASONAL-HISTORY STUDIES OF 1920.

The season of 1920 proved to be quite different from that of 1919. According to the Weather Bureau, the spring was the most backward on record. The first three months of the year were about normal, but April was extremely cold, the mean temperature at Yakima being 5.1° below normal. In May the mean temperature was 2.6° below normal, and in June the mean temperature was 2.3° below normal. This resulted in greatly retarding the activities of the codling moth. Apple trees bloomed at Yakima May 6 to 10, and the calyx spray was applied about May 20, or 10 days later than in 1919. After July 1 the temperatures were above normal. The cold spring resulted in slowing up the various stages of the spring brood of the codling moth. Beginning with the incubation of the first brood of eggs, however, the periods were shorter than the corresponding ones of 1919. In spite of this the seasonal history continued throughout the summer to be later than in 1919. The studies recorded below were carried out in the same way as in 1919, and each table should be considered as a unit.

WINTERING LARVÆ.

In order to provide material for the 1920 studies, a large number of wintering larvæ were secured in the fall of 1919 from reared material and from banded trees. The extremely cold weather of December, described on page 58, killed all these larvæ, and it was necessary to collect a new supply in February and March. These were collected wherever they had escaped the freeze, many of them being taken from the soil about the bases of trees and from bands which were covered with snow during the freeze.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—In Figure 12 is given the time of pupation of 160 individuals of the spring brood. The effect of the cold weather in April is very noticeable. Two larvæ pupated on April 3, and there were no more until April 12. The maximum occurred April 26 and

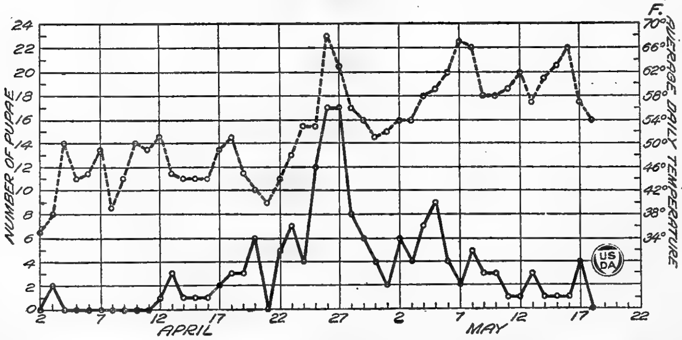

FIG. 12.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1920.

27, however, which is the same time as the maximum for 1919. Pupation ended on May 17, with a single late straggler on June 3.

Length of the pupal stage.—Table 18 shows the length of the pupal stage of 136 pupæ, the average being 33.56 days, two days longer than in 1919.

TABLE 18.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1920.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Apr. 3	2	42.00	42	42	Apr. 30	4	33.75	35	33
12	1	36.00	36	36	May 1	2	34.00	34	34
13	3	36.00	37	34	2	4	32.50	34	32
14	1	36.00	36	36	3	4	31.25	32	31
15	1	31.00	31	31	4	5	31.00	31	31
16	1	34.00	34	34	5	5	31.00	31	31
17	2	32.50	33	32	6	3	31.67	32	31
18	2	37.00	37	37	7	1	34.00	34	34
19	3	33.67	37	31	8	3	33.33	35	32
20	6	33.00	35	32	9	2	34.00	34	34
22	5	32.00	34	30	10	2	33.50	34	33
23	7	32.86	35	32	12	1	32.00	32	32
24	3	32.00	32	32	13	3	32.33	34	31
25	11	31.91	36	31	14	1	33.00	33	33
26	14	35.57	38	34	15	1	34.00	34	34
27	15	35.33	37	34	16	1	33.00	33	33
28	8	33.25	37	27	17	3	32.67	33	32
29	6	34.50	35	34					

Total number of pupæ	136
Average length of pupal stage in days	33.56
Maximum length of pupal stage in days	42
Minimum length of pupal stage in days	27

MOTHS OF THE SPRING BROOD.

Time of emergence.—Moths began emerging May 10, but the cold weather held them back, and the maximum period of emergence did not occur until May 25 to June 5, with a maximum of 115 moths on June 2, which was 12 days later than in 1919. Moths continued emerging until July 2. These records will be found in Figure 13.

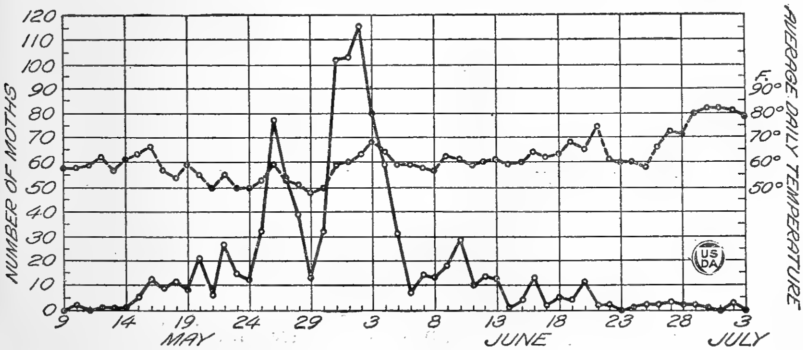

FIG. 13.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1920.

Oviposition by moths of the spring brood.—Oviposition records were obtained from 824 moths confined in cages of about 25 moths each, and tabulated in Table 19. The averages are cage and not individual averages. (See p. 68 for some individual averages.)

TABLE 19.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1920.*

Observation.	Number of moths	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	6	1	5	May 15	May 19	May 24	June 8	4	9	21	24	9
2	12	9	3	May 16	May 26	June 19	June 19	10	34	25	34	23
3	9	8	1	May 17	....	....	....	......	......	......	......	0
4	11	7	4	May 18	May 26	June 3	June 4	8	16	10	17	13
5	8	7	1	May 19	June 11	June 11	June 11	23	23	1	23	5
6	21	13	8	May 20	May 31	May 31	June 8	11	11	9	19	32
7	6	5	1	May 21	....	....	....	......	......	......	......	0
8	25	12	13	May 22	May 26	June 3	June 13	4	12	19	22	33
9	14	11	3	May 23	May 31	...do.....	June 3	8	11	4	11	4
10	12	11	1	May 24	June 3	June 9	June 12	10	16	10	19	6
11	32	19	13	May 25	May 31	...do.....	June 21	6	15	22	27	177
12	71	29	42	May 26	...do.....	June 3	June 14	5	8	15	19	129
13	48	24	24	May 27	June 1	June 8	...do.....	5	12	14	18	169
14	40	25	15	May 28	...do.....	June 11	June 15	4	14	15	18	59
15	13	5	8	May 29	June 20	June 20	June 25	22	22	6	27	3
16	32	16	16	May 30	June 2	June 8	June 8	3	9	7	9	11
17	75	32	43	May 31	June 3	June 4	June 26	3	4	24	26	53
18	75	26	49	June 1	...do.....	June 18	June 29	2	17	27	28	220
19	50	16	34	June 2	June 4	June 20	...do.....	2	18	26	27	167
20	50	18	32	June 3	...do.....	June 9	June 28	1	6	25	25	374
21	50	16	34	June 4	June 5	June 12	...do.....	1	8	24	24	274
22	29	9	20	June 5	June 8	June 18	...do.....	3	13	21	23	210
23	7	4	3	June 6	June 26	June 26	June 27	20	20	2	21	6
24	14	4	10	June 7	June 12	June 15	June 29	5	8	18	22	194
25	13	5	8	June 8	June 16	June 30	June 30	8	22	15	22	34
26	17	8	9	June 9	June 12	June 15	June 28	3	6	17	19	79
27	26	6	20	June 10	June 13	June 21	June 29	3	11	17	19	31
28	9	5	4	June 11	June 20	June 23	June 25	9	12	6	14	10
29	13	9	4	June 12	June 18	June 27	June 29	6	15	12	17	90
30	12	5	7	June 13	June 17	June 21	July 1	4	8	15	18	267
31	13	4	9	June 16	June 23	June 29	...do.....	7	13	9	15	21
32	11	3	8	June 20	June 26	June 30	July 10	6	10	15	20	68
	Average							6.87	13.43	15.03	20.90	......
	Maximum							23	34	27	34	......
	Minimum							1	4	1	9	......

Number of male moths	372
Number of female moths	452
Total number of moths	824
Total number of eggs	2,771
Average number of eggs per female moth	6.13

Number of eggs per female moth.—Of the moths in these cages, 452 were females. These deposited 2,771 eggs, or an average of 6.13 eggs per female, as shown in Table 19.

Length of life of moths.—Male moths lived an average of 16.65 days; females, 17.73 days. These data are detailed in Table 20. The average life was somewhat longer than in 1919, owing to the cooler weather.

TABLE 20.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1920.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
2	4	2	2	17	18	17	21	32	4	32	0
3	10	3	8	18	15	18	33	33	2	33	3
4	6	4	3	19	12	19	17	34	2	34	1
5	9	5	5	20	12	20	20	35	4	35	1
6	7	6	4	21	11	21	20	36	4	36	0
7	9	7	6	22	11	22	16	37	1	37	0
8	20	8	12	23	4	23	14	38	2	38	0
9	12	9	11	24	16	24	20	39	1	39	0
10	19	10	15	25	10	25	12	40	1	40	0
11	13	11	18	26	8	26	16	41	3	41	0
12	16	12	16	27	4	27	17	43	2	43	0
13	17	13	23	28	5	28	12	45	0	45	2
14	20	14	26	29	6	29	9				
15	26	15	38	30	0	30	3	Total.	368	Total.	455
16	18	16	24	31	4	31	7				

Average length of life of male moths, 16.65 days; female moths, 17.73 days.
Maximum length of life of male moths, 43 days; female moths, 45 days.
Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—Spring-brood moths began ovipositing May 12, but owing to cold weather very few eggs were deposited before May 31, as shown in Figure 14. From then on eggs were

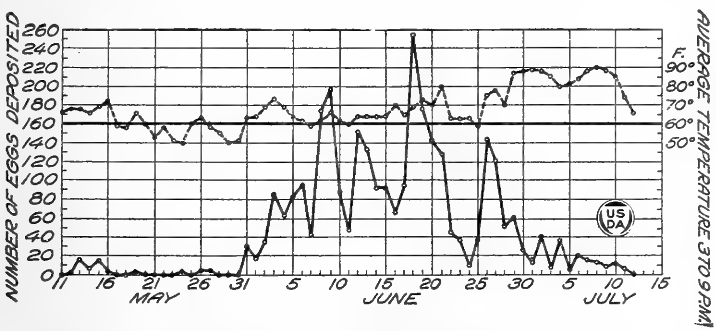

FIG. 14.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1920.

deposited daily until July 11, with a maximum on June 18, 14 days later than the 1919 maximum. The temperature curve in Figure 14 shows for each day the average temperature for the period between 3 p. m. and 9 p. m., as this is the period during which most of the eggs are deposited.

Length of incubation.—Observations were made on 1,010 eggs for the length of incubation. These and other data on the development of the eggs are given in Table 21.

TABLE 21.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1920.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
May 31	8	4.00	4	4	9.00	9	9	12.13	13	12
June 1	3	4.00	4	4	10.00	10	10	12.33	13	12
3	5	4.00	4	4	11.00	11	11	13.20	14	13
4	12	5.00	5	5	12.00	12	12	14.75	15	14
5	27	5.00	5	5	11.30	12	11	13.30	14	12
6	59	5.00	5	5	11.00	11	11	13.07	14	13
7	10	6.00	6	6	11.00	11	11	12.60	13	12
8	108	5.10	6	5	10.10	11	10	12.49	14	12
9	104	5.00	5	5	10.00	10	10	11.61	12	11
10	39	5.00	5	5	10.00	10	10	11.00	11	11
11	4	5.00	5	5	9.00	9	9	10.75	11	10
12	28	5.00	5	5	9.00	9	9	10.25	11	10
13	46	5.00	5	5	8.20	9	8	11.04	12	10
14	18	4.00	4	4	8.11	9	8	11.00	12	10
15	55	4.00	4	4	8.07	9	8	11.00	12	10
16	35	4.00	4	4	8.00	8	8	10.89	11	10
17	34	3.00	3	3	8.18	11	8	11.24	13	11
18	175	3.00	3	3	9.04	10	9	10.17	12	10
19	31	4.00	4	4	9.16	10	9	10.35	12	10
20	61	3.00	3	3	8.02	9	8	9.54	11	9
21	23	5.00	5	5	8.00	8	8	9.30	10	9
22	1	5.00	5	5	8.00	8	8	9.00	9	9
24	3	5.00	5	5	6.00	6	6	7.33	8	7
25	5	4.00	4	4	6.00	6	6	7.20	8	7
26	28	4.00	4	4	5.00	5	5	6.36	7	6
27	13	4.00	4	4	5.00	5	5	6.00	6	6
28	4	4.00	4	4	5.00	5	5	6.25	7	6
29	10	3.00	3	3	4.00	4	4	6.20	7	6
30	2	3.00	3	3	4.00	4	4	6.50	7	6
July 1	1	3.00	3	3	5.00	5	5	6.00	6	6
2	25	2.00	2	2	4.00	4	4	6.04	7	6
3	3	2.00	2	2	5.00	5	5	6.00	6	6
4	18	4.00	4	4	5.00	5	5	6.06	7	6
6	5	3.00	3	3	4.80	5	4	5.80	6	5
7	7	4.00	4	4	5.57	6	5	7.00	7	7
	1,010	4.14	6	2	8.75	12	4	10.60	15	5

LARVÆ OF THE FIRST BROOD.

Time of hatching.—The earliest larvæ hatched June 12 and hatching continued until July 14, a total period of 33 days, as shown in Figure 15. Most of the larvæ hatched from June 19 to 29, inclusive, with a maximum on June 28, 16 days after the first larva hatched. The maximum occurred 10 days later than in 1919, and the total hatching period was 10 days longer than in 1919.

Length of feeding period, stock-jar method.—The average feeding period of 268 larvæ (both transforming and nontransforming) by the stock-jar method was 19.05 days. (See Table 22.)

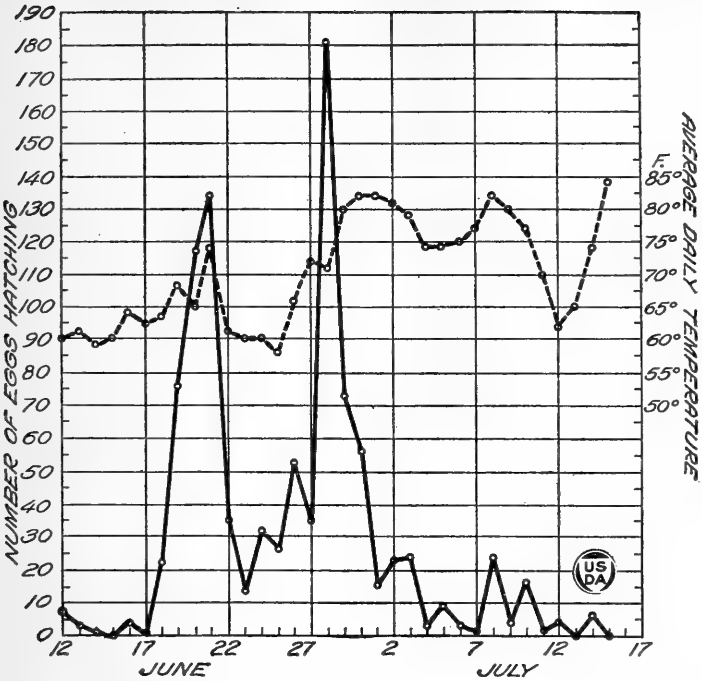

FIG. 15.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1920.

TABLE 22.—*Length of feeding period of larvæ of the first brood of the codling moth, stock-jar method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 18	2	20.00	20	20	July 3	22	20.41	30	10
19	1	17.00	17	17	4	18	18.11	22	11
20	14	20.29	30	17	5	16	19.06	26	13
21	10	20.20	24	17	6	11	19.73	31	12
22	7	19.71	24	17	7	7	17.71	20	16
23	6	18.83	23	16	8	6	21.50	25	19
24	8	17.50	20	15	9	12	21.33	26	17
25	4	16.00	17	15	10	14	20.36	23	18
26	15	18.60	24	15	11	6	17.83	21	14
27	13	17.54	22	13	12	2	16.50	17	16
28	7	18.29	20	16	13	1	21.00	21	21
29	18	17.72	23	14	14	7	21.29	33	17
30	12	16.83	20	14	15	3	20.67	27	17
July 1	12	16.83	19	15	16	2	16.00	16	16
2	10	21.30	29	16	17	2	21.00	22	20

Total number of larvæ	268
Average length of feeding period in days	19.05
Maximum length of feeding period in days	33
Minimum length of feeding period in days	10

Length of feeding period, bagged-fruit method.—Where the bagged-fruit method of feeding was used, the average period was 20.28 days. (See Table 23.)

TABLE 23.—*Length of feeding period of larvæ of the first brood of the codling moth, bagged-fruit method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 24	9	21.22	26	18	June 30	4	17.25	20	15
26	5	19.00	23	16	July 1	14	21.57	28	17
27	3	20.00	26	15	2	4	20.50	24	18
28	4	18.25	19	17	3	4	22.25	24	20
29	10	19.50	24	14					

Total number of larvæ 57
Average length of feeding period in days 20.28
Maximum length of feeding period in days 28
Minimum length of feeding period in days 14

Length of cocooning period.—The cocooning period, or the total period from the time the larva leaves the fruit until it pupates, averaged 5.48 days for 235 transforming individuals. (See Table 24.)

TABLE 24.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1920.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 6	1	4.00	4	4	July 24	4	5.00	7	4
7	3	4.33	5	4	25	8	7.00	15	4
8	4	5.25	7	4	26	5	6.40	14	4
9	7	5.57	6	5	27	6	6.50	13	4
10	11	5.55	7	5	28	3	6.33	8	5
11	12	5.42	6	5	29	6	5.17	8	4
12	9	5.11	6	4	30	4	5.50	8	3
13	16	4.13	5	4	31	3	4.00	4	4
14	8	4.63	8	4	Aug. 1	5	5.60	11	4
15	14	5.29	15	3	2	3	4.33	5	4
16	14	4.86	7	4	3	1	5.00	5	5
17	10	4.60	6	3	4	1	10.00	10	10
18	20	5.55	9	3	6	1	4.00	4	4
19	16	6.31	16	4	7	1	5.00	5	5
20	11	6.18	10	5	11	1	4.00	4	4
21	10	5.70	7	4					
22	6	5.83	10	4	Total.	235	5.48	22	3
23	11	6.91	22	4					

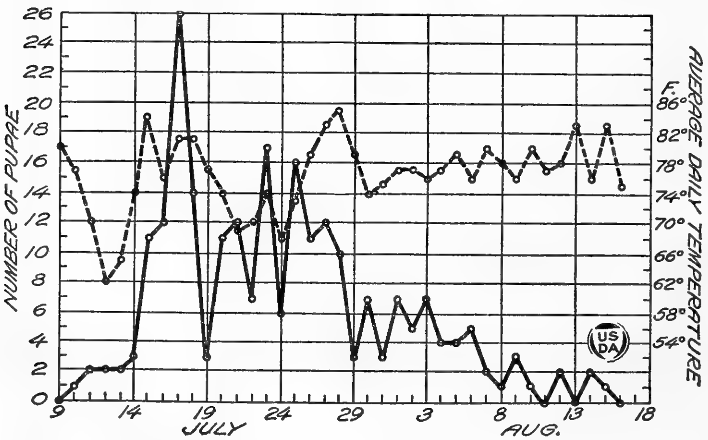

FIG. 16.—Pupation of the first brood of the codling moth at Yakima, Wash., 1920.

PUPÆ OF THE FIRST BROOD.

Time of pupation.—The first pupa occurred July 10, and larvæ continued to pupate until August 15, with a maximum on July 17, as shown in Figure 16.

Length of pupal stage.—The average length of the pupal stage of 219 pupæ was 12.37 days, as shown in Table 25.

TABLE 25.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1920.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 10	1	13.00	13	13	July 27	11	11.82	13	11
11	2	14.00	14	14	28	10	12.20	13	11
12	2	12.50	13	12	29	3	12.00	13	11
13	2	13.00	13	13	30	7	12.71	16	12
14	3	12.00	12	12	31	3	11.00	11	11
15	11	12.45	14	12	Aug. 1	7	10.86	13	7
16	11	12.82	14	11	2	4	11.50	12	11
17	25	12.56	14	11	3	7	11.57	12	11
18	12	12.17	14	11	4	4	12.00	12	12
19	3	12.67	14	12	5	4	11.75	14	11
20	11	13.18	14	11	6	4	13.75	14	13
21	10	12.70	13	11	7	1	12.00	12	12
22	6	12.00	13	11	8	1	15.00	15	15
23	17	11.82	13	10	9	1	13.00	13	13
24	6	11.83	13	11	10	1	14.00	14	14
25	14	12.21	14	11	12	2	17.50	19	16
26	11	11.82	13	11	14	2	18.50	20	17

Total number of pupæ	219
Average length of the pupal stage in days	12.37
Maximum length of the pupal stage in days	20
Minimum length of the pupal stage in days	7

MOTHS OF THE FIRST BROOD.

Time of emergence.—Moths began emerging July 23 and continued until September 30, the maximum occurring on August 15, although the maximum period of emergence extended from July 27 to August 24. (See fig. 17.) This is about 10 days later than the maximum period for 1919.

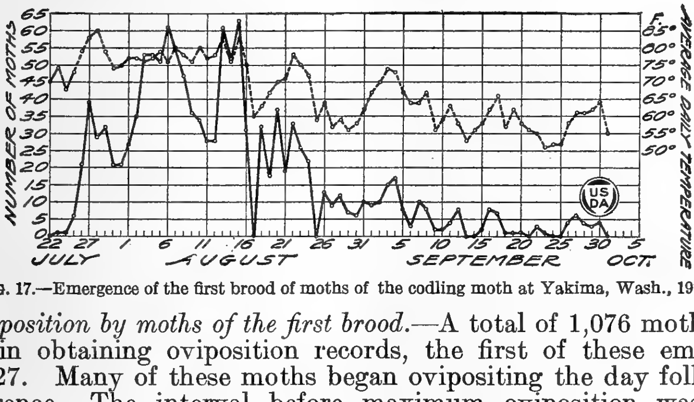

FIG. 17.—Emergence of the first brood of moths of the codling moth at Yakima, Wash., 1920

Oviposition by moths of the first brood.—A total of 1,076 moths was used in obtaining oviposition records, the first of these emerging July 27. Many of these moths began ovipositing the day following emergence. The interval before maximum oviposition was 67.0 days. This is shown in Table 26, the averages being for cages and not individuals.

Number of eggs per female moth.—Table 26 shows that 620 females deposited 13,615 eggs.

TABLE 26.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1920.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	38	10	28	July 27	July 28	Aug. 3	Aug. 13	1	7	17	17	1,067
2	28	10	18	July 28	July 29	Aug. 2	Aug. 17	1	5	20	20	978
3	30	18	12	July 29	July 30	Aug. 7	Aug. 13	1	9	15	15	868
4	19	10	9	July 30	Aug. 1	Aug. 5	Aug. 16	2	6	16	17	654
5	18	6	12	July 31	Aug. 2	Aug. 4	Aug. 13	2	4	12	13	925
6	25	7	18	Aug. 1	...do.....	Aug. 3	Aug. 10	1	2	9	9	72
7	25	10	15	Aug. 2	Aug. 3	...do.....	Aug. 13	1	1	11	11	217
8	51	16	35	Aug. 3	Aug. 4	Aug. 6	Aug. 15	1	3	12	12	813
9	51	23	28	Aug. 4	Aug. 5	...do.....	Aug. 20	1	2	16	16	639
10	51	23	28	Aug. 5	Aug. 6	Aug. 7	Aug. 21	1	2	16	16	484
11	62	29	33	Aug. 6	Aug. 7	Aug. 9	Aug. 20	1	3	14	14	781
12	52	24	28	Aug. 7	Aug. 8	...do.....	Aug. 23	1	2	16	16	575
13	45	20	25	Aug. 8	Aug. 9	Aug. 12	Aug. 22	1	4	14	14	303
14	36	13	23	Aug. 9	Aug. 11	Aug. 15	Aug. 23	2	6	13	14	407
15	27	13	14	Aug. 10	...do.....	Aug. 14	Aug. 26	1	4	16	16	460
16	18	8	10	Aug. 11	Aug. 13	...do.....	Sept. 1	2	3	20	21	343
17	26	10	16	Aug. 12	Aug. 14	Aug. 22	...do.....	2	10	19	20	49
18	55	24	31	Aug. 13	...do.....	Aug. 15	Aug. 31	1	2	18	18	318
19	45	18	27	Aug. 14	Aug. 15	Aug. 24	Sept. 1	1	10	18	18	360
20	57	22	35	Aug. 15	Aug. 16	Aug. 22	Sept. 2	1	7	18	18	170
21	24	12	12	Aug. 18	Aug. 21	Aug. 23	Sept. 5	3	5	16	18	303
22	25	9	6	Aug. 19	Aug. 22	...do.....	Sept. 8	3	4	18	20	173
23	15	12	13	Aug. 20	...do.....	...do.....	Sept. 6	2	3	16	17	428
24	29	6	13	Aug. 21	Aug. 23	Sept. 2	Sept. 4	2	12	13	14	29
25	12	17	15	Aug. 22	...do.....	Aug. 23	Sept. 10	1	1	19	19	244
26	35	12	13	Aug. 23	Aug. 26	Aug. 26	Sept. 8	3	3	14	16	176
27	21	9	12	Aug. 24	Aug. 31	Sept. 2	Sept. 19	7	9	20	26	115
28	23	5	8	Aug. 26	Aug. 30	...do.....	Sept. 17	4	7	19	22	31
29	19	3	6	Aug. 27	Sept. 1	Sept. 3	Sept. 15	5	7	15	19	162
30	11	6	5	Aug. 28	Sept. 2	Sept. 7	Sept. 12	5	10	11	15	121
31	8	3	5	Aug. 29	Sept. 3	Sept. 4	Sept. 7	5	6	5	9	17
32	6	1	5	Aug. 30	Sept. 4	Sept. 16	Sept. 28	5	17	25	29	65
33	8	3	5	Aug. 31	Sept. 3	Sept. 10	Sept. 21	3	10	19	21	113
34	9	4	5	Sept. 1	Sept. 4	Sept. 4	Sept. 17	3	3	14	16	285
35	9	4	5	Sept. 2	...do.....	...do.....	Sept. 18	2	2	15	16	5
36	14	4	10	Sept. 3	...do.....	Sept. 6	Sept. 29	1	3	26	26	179
37	17	10	7	Sept. 4	Sept. 7	Sept. 10	Sept. 24	3	6	18	20	100
38	8	3	5	Sept. 5	...do.....	Sept. 16	Sept. 20	2	11	14	15	34
39	3	1	2	Sept. 6	Sept. 16	...do.....	Sept. 26	10	10	11	20	66
40	10	5	5	Sept. 7	Sept. 12	Sept. 14	Sept. 27	5	7	16	20	96
41	8	5	3	Sept. 8	Sept. 9	Sept. 12	Oct. 1	1	4	23	23	246
42	8	3	5	Sept. 12	Sept. 16	Sept. 18	Sept. 30	4	6	15	18	97
43	8	4	4	Sept. 16	Sept. 30	Oct. 4	Oct. 8	14	18	9	22	40
44	7	1	6	Sept. 17	Sept. 28	Sept. 28	Oct. 7	11	11	10	20	7
Average								2.93	6.07	15.70	17.64	......
Maximum								14	18	26	29	......
Minimum								1	1	5	9	......

Number of male moths	456
Number of female moths	620
Total number of moths	1,076
Total number of eggs	13,615
Average number of eggs per female moth	21.96

Length of life of moths.—Male moths lived an average of 13.87 days; females, 13.24 days. These data are given in Table 27.

TABLE 27.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1920.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	0	1	2	14	21	14	21	27	7	27	0
2	5	2	7	15	25	15	30	28	4	28	3
3	6	3	16	16	21	16	30	29	3	29	2
4	6	4	17	17	16	17	20	30	1	30	3
5	20	5	31	18	15	18	31	31	1	31	1
6	14	6	22	19	9	19	15	32	2	32	2
7	14	7	29	20	16	20	16	34	1	34	2
8	26	8	21	21	20	21	23	35	0	35	1
9	23	9	28	22	8	22	8	38	0	38	1
10	22	10	28	23	7	23	9	39	0	39	1
11	20	11	41	24	5	24	9	40	0	40	1
12	18	12	28	25	2	25	5				
13	27	13	35	26	6	26	7	Total.	391	Total.	546

Average length of life of male moths, 13.87 days; female moths, 13.24 days.
Maximum length of life of male moths, 34 days; female moths, 40 days.
Minimum length of life of male moths, 2 days; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Life-cycle, stock-jar feeding method.—Table 28 gives the life cycle of 177 individuals of the first generation, all of which were reared from egg to moth, the larvæ being fed by the stock-jar method. The incubation period averaged 8.98 days, the larval feeding period 18.21 days, the cocooning period 5.44 days, the pupal period 12.45 days, and the life cycle 45.08 days. To this must be added 2.93 days, which is the average interval between emergence of the first-brood moth and egg deposition, in order to obtain the complete life cycle from deposition of first-brood egg to deposition of second-brood egg. This gives a complete life cycle of 48.01 days.

TABLE 28.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1920.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
June 5	2	13	20.00	20	20	6.00	7	5	12.50	13	12	51.50	52	51
6	1	13	17.00	17	17	4.00	4	4	13.00	13	13	47.00	47	47
8	12	12	20.33	30	17	4.75	6	4	12.83	14	12	49.91	59	47
9	9	12	20.00	24	17	5.22	7	3	12.67	14	11	49.89	55	47
12	6	10	20.00	24	17	4.83	6	4	12.50	13	12	47.33	52	44
13	6	10	18.83	23	16	5.17	6	4	12.83	14	12	46.83	51	43
13	7	11	17.14	20	15	5.14	7	4	12.00	13	11	45.28	47	44
14	4	11	16.00	17	15	5.25	6	5	13.25	14	13	45.50	46	45
15	11	11	18.45	24	15	5.09	6	3	13.18	14	12	47.72	54	44
16	9	11	17.44	22	13	4.89	6	4	12.44	14	11	45.77	52	41
18	6	10	18.00	20	16	5.00	7	4	12.33	13	11	45.33	49	42
19	11	10	17.09	23	14	4.73	6	4	12.82	14	11	44.64	51	39
20	8	10	16.75	20	14	5.13	7	3	12.13	13	11	44.01	48	40
21	9	10	16.56	18	15	6.44	16	4	11.89	13	11	44.89	56	42
26	4	6	20.25	28	16	4.75	7	3	12.00	13	11	43.00	48	40
26	15	7	18.87	29	10	6.27	11	4	12.33	16	11	44.47	54	32
28	12	6	16.83	22	11	7.83	22	4	12.83	20	11	43.49	67	33
29	7	6	16.71	24	13	5.29	7	4	11.14	12	9	39.14	46	34
29	9	7	18.44	31	12	5.56	8	4	11.89	14	11	42.89	56	37
30	5	7	17.20	19	16	4.40	5	4	11.40	12	11	40.00	42	38
July 2	2	6	20.50	22	19	4.50	5	4	12.50	13	12	43.50	44	43
3	3	6	21.33	26	17	7.00	10	4	14.00	17	12	48.33	59	39
4	5	6	19.60	23	18	5.60	8	4	11.80	14	11	43.00	47	40
4	4	7	17.25	21	14	6.75	11	4	11.50	16	7	42.50	55	35
6	1	6	17.00	17	17	5.00	5	5	12.00	12	12	40.00	40	40
6	1	7	21.00	21	21	5.00	5	5	15.00	15	15	48.00	48	48
7	4	7	18.75	24	17	4.25	5	4	13.75	19	12	43.75	55	40
8	2	7	17.50	18	17	4.50	5	4	14.00	14	14	43.00	43	43
9	2	7	16.00	16	16	4.00	4	4	11.00	11	11	38.00	38	38
	177	[2]8.98	18.21	31	10	5.44	22	3	12.45	20	7	45.08	67	32

[1] Add 2.93 days for complete life cycle. [2] Average.

Life cycle, bagged-fruit feeding method.—The life cycle of 43 individuals fed by the bagged-fruit method is given in Table 29. Here the incubation period averaged 9.79 days, the larval feeding period 19.58 days, the cocooning period 5.18 days, the pupal period 12.02 days, and the life cycle 46.57 days, or, adding 2.93 days for the interval between emergence of the moth and egg deposition, 49.50 days for the complete life cycle.

TABLE 29.—*Life cycle of the first generation of the codling moth as observed by rearing, bagged-fruit feeding method, Yakima, Wash., 1920.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period.			Cocooning period.			Pupal period.			Life cycle.[1]		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
		Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.	Days.
June 13	4	11	20.00	21	18	8.75	15	5	12.25	13	11	52.00	60	47
15	5	11	19.00	23	16	5.00	6	4	12.00	14	11	47.00	52	43
16	3	11	20.00	26	15	5.00	5	5	13.00	13	13	49.00	55	44
18	3	10	18.33	19	17	3.66	4	3	12.00	13	11	43.99	46	42
19	7	10	18.57	22	14	5.14	9	4	12.00	14	11	45.71	49	39
20	3	10	16.33	17	15	3.33	4	3	12.00	13	11	41.66	43	41
21	11	10	20.55	26	17	5.45	8	5	11.64	13	11	47.64	53	43
25	3	7	19.33	21	18	5.00	5	5	12.33	13	12	43.66	46	42
26	4	7	22.25	24	20	4.00	4	4	12.00	13	11	45.25	47	42
	43	9.79	19.58	26	14	5.18	15	3	12.02	14	11	46.57	60	39

[1] Add 2.93 days for complete life cycle.

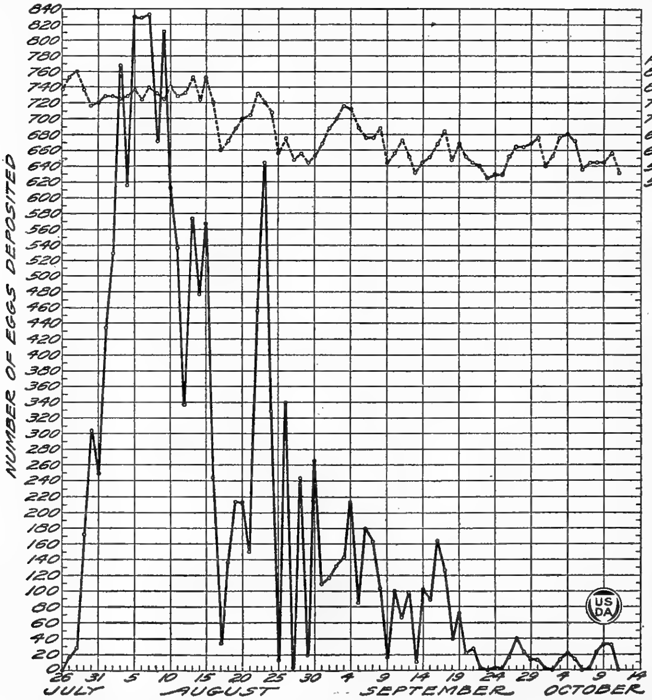

FIG. 18.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1920.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The earliest second-brood eggs were deposited July 27, and eggs were deposited almost continuously thereafter until October 10, with a maximum period of oviposition extending practically throughout the month of August, as shown in Figure 18. The actual maximum of 833 eggs occurred on August 7, only 11 days after the first egg was deposited.

Length of incubation.—The incubation period for 4,135 eggs was determined and the data on the various changes in the eggs are shown in Table 30. It will be seen that the average length of incubation was 8.74 days, closely approximating that of 1919.

TABLE 30.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1920.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of— Red ring. Average.	Red ring. Maximum.	Red ring. Minimum.	Black spot. Average.	Black spot. Maximum.	Black spot. Minimum.	Incubation period in days. Average.	Incubation period in days. Maximum.	Incubation period in days. Minimum.
July 27	4	3.00	3	3	5.00	5	5	6.00	6	6
28	9	4.00	4	4	5.00	5	5	6.00	6	6
29	21	3.00	3	3	5.00	5	5	6.14	7	6
30	101	2.00	2	2	5.00	5	5	6.43	7	6
31	34	3.00	3	3	5.00	5	5	6.09	7	6
Aug. 1	119	3.00	3	3	5.00	5	5	6.45	8	6
2	148	2.00	2	2	5.00	5	5	6.02	7	6
3	115	2.00	2	2	5.00	5	5	6.00	6	6
4	150	3.00	3	3	5.00	5	5	6.00	6	6
5	139	3.00	3	3	5.00	5	5	6.06	7	6
6	230	2.00	2	2	5.00	5	5	6.00	6	6
7	268	3.00	3	3	5.00	5	5	6.08	7	6
8	237	3.00	3	3	5.00	5	5	6.06	7	6
9	282	3.00	3	3	5.00	5	5	6.02	7	6
10	159	2.00	2	2	5.00	5	5	6.00	6	6
11	82	3.00	3	3	4.00	4	4	5.85	7	5
12	60	3.00	3	3	4.00	4	4	6.67	8	6
13	132	4.00	4	4	6.00	6	6	7.95	8	7
14	111	3.00	3	3	6.00	6	6	8.14	9	7
15	274	3.00	3	3	7.00	7	7	8.00	8	8
16	56	4.93	6	4	7.00	7	7	8.46	9	8
17	1	4.00	4	4	6.00	6	6	7.00	7	7
18	22	4.00	4	4	6.00	6	6	8.50	9	8
19	44	3.02	4	3	6.93	8	6	8.93	10	8
20	82	4.00	4	4	7.78	8	7	10.78	11	10
21	21	3.19	4	3	8.10	9	7	11.05	12	9
22	28	3.07	4	3	8.71	10	8	11.71	13	11
23	237	3.00	3	3	10.00	10	10	12.03	13	12
24	110	4.00	4	4	11.00	11	11	12.00	12	12
26	126	4.00	4	4	9.00	9	9	10.75	11	10
28	134	5.00	5	5	8.03	9	8	10.31	12	10
29	6	3.00	3	3	8.00	8	8	9.17	10	9
30	70	3.00	3	3	8.03	9	8	9.34	11	9
31	14	3.07	4	3	7.79	9	7	9.79	11	9
Sept. 1	19	3.00	3	3	8.05	9	8	10.79	12	10
2	16	4.81	5	4	8.81	9	8	11.75	12	10
3	32	3.00	3	3	11.00	11	11	14.06	15	14
4	100	3.12	4	3	13.12	14	13	14.84	16	14
5	19	4.00	4	4	13.00	13	13	14.92	15	14
6	17	4.00	4	4	13.00	13	13	15.82	17	15
7	80	4.53	5	4	14.53	15	14	18.78	20	17
8	19	4.21	5	4	14.21	15	14	18.00	19	17
10	31	5.00	5	5	15.29	16	15	19.23	20	18
11	23	4.09	5	4	16.43	17	16	18.52	20	18
12	5	4.60	5	4	16.00	16	16	19.00	20	18
13	1	4.00	4	4	16.00	16	16	18.00	18	18
14	20	4.15	5	4	15.85	16	15	18.00	19	17
15	27	4.96	5	4	15.19	16	14	19.19	20	18
16	43	5.05	6	5	15.26	16	15	18.30	20	18
17	40	6.30	7	5	15.65	16	15	18.88	20	18
19	6	4.83	5	4	15.50	16	15	17.50	19	16
20	2	7.00	7	7	16.00	16	16	21.00	21	21
21	9	8.22	9	8	17.22	18	17	21.00	22	20
	4,135	3.19	9	2	7.14	18	4	8.74	22	5

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LARVÆ OF THE SECOND BROOD.

Time of hatching.—Second-brood larvæ were hatching during a period of over 10 weeks, beginning August 2 and ending October 13. The maximum period of hatching extended from August 6 to September 6, with an actual maximum on August 12, as shown in Figure 19.

Length of feeding period, stock-jar method.—Table 31 shows the average feeding period of 594 larvæ reared by the stock-jar method.

TABLE 31.—*Length of feeding period of larvæ of the second brood of the codling moth, stock-jar method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Aug. 3	3	22.33	25	17	Aug. 21	20	42.05	68	29
4	6	19.50	21	17	22	22	39.36	60	25
5	14	24.14	33	17	23	27	44.11	65	25
6	30	26.73	44	17	24	23	44.13	63	24
7	12	26.08	36	20	25	10	45.10	61	31
8	35	29.43	49	18	26	15	37.13	48	22
9	53	30.21	60	20	27	4	43.75	61	32
10	43	29.63	54	18	28	5	40.60	59	33
11	39	34.59	70	22	29	1	41.00	41	41
12	29	28.00	48	23	30	6	40.17	53	33
13	28	36.36	70	24	31	7	44.14	57	30
14	38	35.11	64	18	Sept. 1	3	47.00	56	29
15	22	37.68	51	22	2	4	46.00	53	35
16	20	35.70	55	18	3	11	48.55	57	35
17	9	39.22	49	27	4	3	50.67	54	48
18	8	41.38	71	29	5	11	50.00	62	40
19	12	31.83	43	26	6	3	49.33	54	44
20	17	38.71	59	28	8	1	48.00	48	48

Total number of larvæ	594
Average length of feeding period in days	35.30
Maximum length of feeding period in days	71
Minimum length of feeding period in days	17

Length of feeding period, bagged-fruit method.—In Table 32 will be found the feeding period of 106 larvæ reared by the bagged-fruit method.

Owing to the late season, none of the second-brood larvæ reared in 1920 pupated, hence it is not possible to give any further data for this year.

TABLE 32.—*Length of feeding period of larvæ of the second brood of the codling moth, bagged-fruit method, Yakima, Wash., 1920.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Aug. 7	6	34.17	60	23	Aug. 13	9	36.11	46	27
8	8	33.00	42	26	14	5	44.40	70	25
9	10	33.00	43	25	15	15	43.80	79	32
10	5	31.80	37	23	16	6	46.67	68	34
11	9	36.22	54	26	17	11	45.73	63	21
12	6	33.33	43	25	18	16	49.50	69	37

Total number of larvæ........ 106
Average length of feeding period in days........ 40.22
Maximum length of feeding period in days........ 79
Minimum length of feeding period in days........ 21

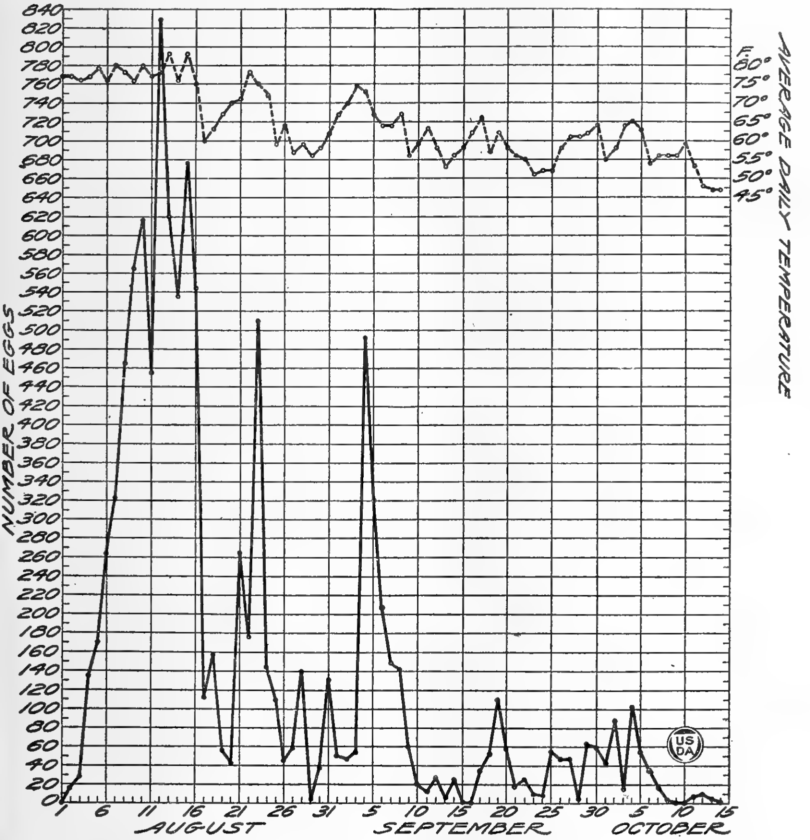

FIG. 19.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1920.

CODLING-MOTH BAND STUDIES OF 1920.

In 1920 trees were again banded in both the Guthrie orchard at Yakima and the Walden orchard near Buena, the larvæ being collected every three days, as in 1919. In the Guthrie orchard, 29 trees were banded, and although these trees were sprayed and

there was a high winter mortality, 5,347 worms were secured, more than twice as many as in 1919. The first worms appeared in the bands on July 8, 15 days later than in 1919, and the maximum for the first brood occurred July 20. The number decreased thereafter until August 19, after which it rose, reaching a maximum for the second brood on September 6, as shown in Figure 20.

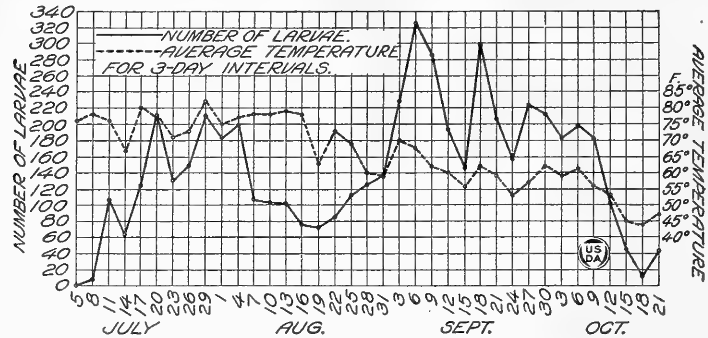

FIG. 20.—Occurrence of codling moth larvæ under bands on apple trees at Yakima, Wash., 1920.

In the Walden orchard, 10 trees were again banded, but the orchard had changed owners, and was very thoroughly sprayed in 1920, with the result that only 665 worms were secured during the season. This was hardly enough to indicate the maximum occurrence of the two broods. The maximum number of first-brood worms was collected on July 17, though nearly as many were found

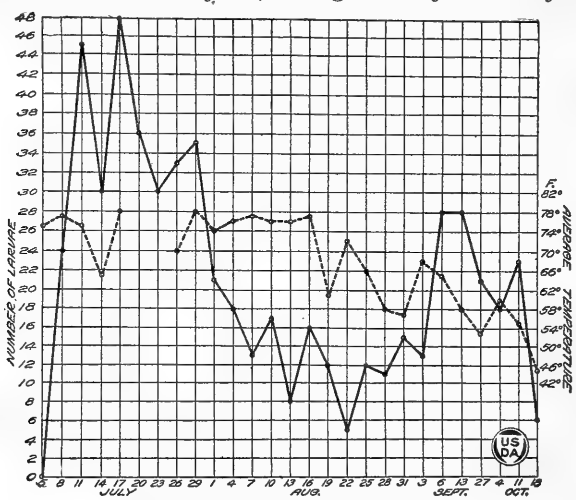

FIG. 21.—Occurrence of codling moth larvæ under bands on apple trees at Buena, Wash., 1920.

on July 11, which is 9 days earlier than the maximum at Yakima. For the second brood, the maximum was not obtained until September 6, the same date as the maximum at Yakima, as shown in Figure 21.

A summary of the seasonal history of the codling moth for 1920 is shown in Figure 22.

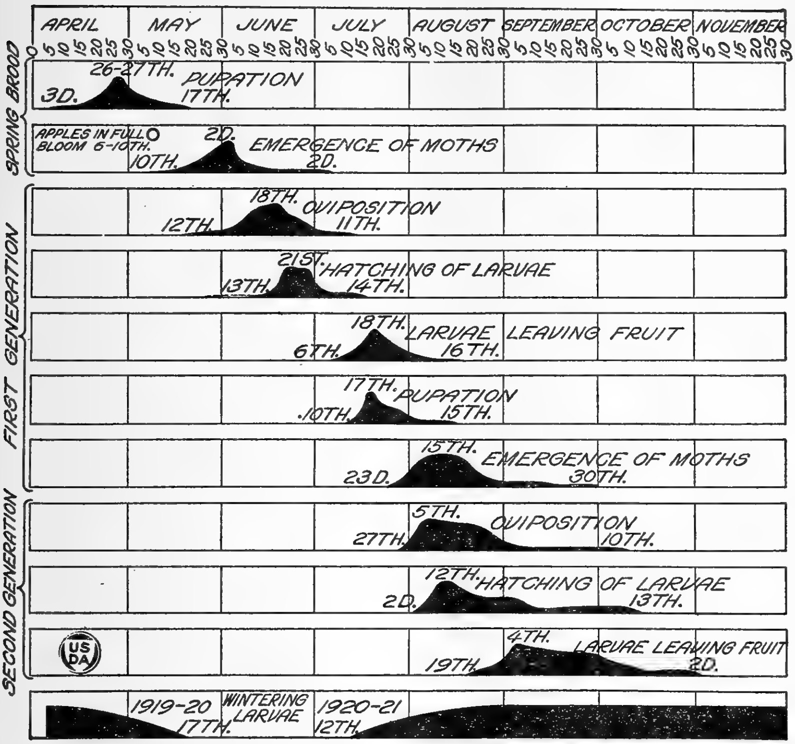

FIG. 22.—Seasonal history of the codling moth at Yakima, Wash., 1920.

SEASONAL HISTORY STUDIES OF 1921.

The life-history studies of the codling moth were continued in 1921 in much the same manner as in the two previous seasons, and considerably more material was handled, especially in the studies of the spring brood. Complete data on wintering larvæ were obtained for the first time. No third-brood larvæ were hatched in the insectary.

The development of the codling moth corresponded closely to that of 1919. Minimum temperatures of 26° and 29° F. on April 24 and 30, respectively, delayed the blooming period of apples so as to extend it over the period from April 26 to May 7. These abnormally low temperatures froze many blossoms, but did not cause a noticeable loss in the apple production of the valley. However, pupal development of the spring brood was interrupted, and two periods of pupation resulted. High temperatures during the time from May 30 to June 6 greatly hastened the development of the codling moth, and many orchardists were late in applying the first cover spray. The remainder of the growing season was favorable and the precipitation was only slightly below normal.

WINTERING LARVÆ.

For the studies of 1921, reared larvæ of the first and second generations of 1920 were used, as well as a considerable number of larvæ collected from banded trees in September, 1920. A special study of the wintering period was made, and the results are given on page 59.

PUPÆ OF THE SPRING BROOD.

Time of pupation.—The time of pupation of 732 wintering larvæ is shown in Figure 23. An unusually cold period, with daily mean temperatures below 50° F. extending from April 22 to May 3 (April 28 excepted), followed by warmer weather, caused an abundance of larvæ to pupate at two widely separated periods. The first maximum

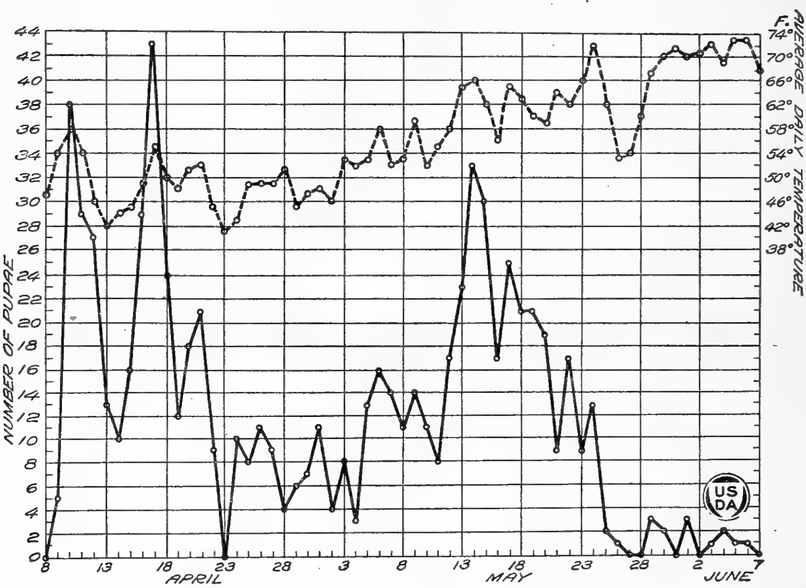

FIG. 23.—Pupation of the spring brood of the codling moth at Yakima, Wash., 1921.

was reached on April 17 and the second maximum on May 14. The first pupa was observed on April 9 and the last on June 6, giving a range of 59 days.

Length of the pupal stage.—Although 229 of the 553 pupæ recorded in Table 33 pupated before April 22, with a minimum average pupal period of 36 days, the extremely high temperatures in the latter part of May and early June so shortened the pupal period of the remaining individuals that the average for all pupæ was 29.53 days. This is the lowest average pupal period for the spring brood that has been recorded in these studies at Yakima.

TABLE 33.—*Length of the pupal stage of pupæ of the spring brood of the codling moth, Yakima, Wash., 1921.*

Date of pupation.	Number of pupæ.	Pupal period in days.			Date of pupation.	Number of pupæ.	Pupal period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Apr. 10	35	41.46	43	40	May 6	12	24.67	26	22
11	24	41.38	43	40	7	9	23.33	25	17
12	22	41.05	42	40	8	6	23.83	25	23
13	9	39.89	41	38	9	13	23.31	24	22
14	4	39.00	39	39	10	7	22.86	24	22
15	14	39.07	49	38	11	7	22.29	23	22
16	26	38.12	45	37	12	13	21.77	23	21
17	33	37.06	38	36	13	20	20.90	23	20
18	22	36.64	40	35	14	26	21.00	24	20
19	11	36.00	39	35	15	20	20.25	21	19
20	12	36.00	38	34	16	13	19.85	20	19
21	17	36.06	37	33	17	19	19.21	21	18
22	8	35.50	37	32	18	12	19.25	20	18
24	8	33.75	35	31	19	16	18.94	21	18
25	5	33.40	34	33	20	13	18.46	20	18
26	10	32.00	33	29	21	7	18.43	20	17
27	8	31.50	32	31	22	10	18.50	20	16
28	3	31.00	32	30	23	7	18.71	20	17
29	5	31.20	35	29	24	6	19.33	21	18
30	4	28.25	29	28	25	1	19.00	19	19
May 1	9	28.44	29	28	29	2	19.50	20	19
2	3	27.67	28	27	30	1	13.00	13	13
3	3	26.67	27	26	June 1	2	21.00	21	21
4	3	26.00	27	25	4	1	21.00	21	21
5	11	25.18	26	25	5	1	21.00	21	21

Total number of pupæ 553
Average length of pupal stage in days 29.53
Maximum length of pupal stage in days 49
Minimum length of pupal stage in days 13

MOTHS OF THE SPRING BROOD.

Time of emergence.—Figure 24 indicates graphically the time of emergence of 2,165 spring-brood moths, of which 1,896, or 87.5 per cent, emerged between May 22 and June 6, owing to the high temperatures. The result of daily mean temperatures below 55° F. on May 26 and 27 is clearly shown in the accompanying diagram. The first moth emerged May 19, and the last moth on June 27, with a maximum emergence of 259 moths on May 30.

Oviposition by moths of the spring brood.—The high temperatures previously mentioned created nearly ideal conditions for oviposition by spring-brood moths. Consequently the average number of days before oviposition and from emergence to maximum oviposition was 2.47 and 5.53, respectively, which is noticeably less than the same interval in 1919 and 1920. The moths emerging on June 8, which had a maximum of 18 days for each of these periods, were abnormal in that they laid only 4 eggs. Eggs were deposited on the day after emergence in 9 out of 19 instances. The data in Table 34 are for cages rather than individuals.

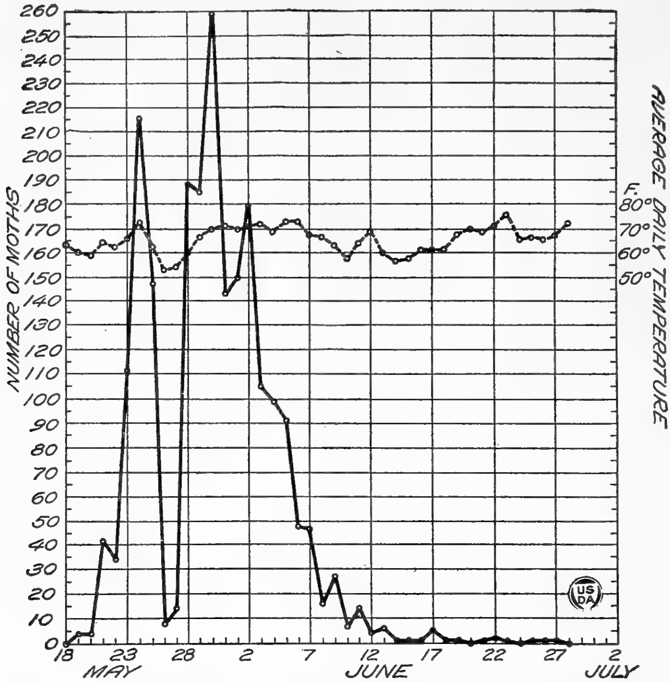

FIG. 24.—Emergence of the spring brood of moths of the codling moth at Yakima, Wash., 1921.

TABLE 34.—*Oviposition by codling moths of the spring brood in rearing cages, Yakima, Wash., 1921.*

Observation.	Number of moths	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	39	33	6	May 21	May 23	May 24	June 8	2	3	17	18	310
2	31	15	16	May 22	May 24	May 25	...do.....	2	3	16	17	726
3	74	45	29	May 23	May 25	May 30	June 13	2	7	20	21	1,042
4	142	66	76	May 24	...do.....	May 31	June 20	1	7	27	27	3,066
5	83	34	49	May 25	May 27	June 4	June 17	2	10	22	23	1,596
6	9	4	5	May 27	May 30	May 30	June 7	3	3	9	11	143
7	110	45	65	May 28	...do.....	June 1	June 12	2	4	14	15	506
8	104	36	68	May 29	...do.....	June 5	June 20	1	7	22	22	508
9	132	44	88	May 30	May 31	June 3	June 22	1	4	23	23	1,251
10	50	26	24	May 31	June 2	June 4	June 19	2	4	18	19	610
11	85	30	55	June 1	...do.....	June 5	June 27	1	4	26	26	1,227
12	91	30	61	June 2	June 3	June 8	June 26	1	6	24	24	794
13	24	9	15	June 3	June 4	June 6	...do.....	1	3	23	23	309
14	61	18	43	June 4	June 5	...do.....	June 22	1	2	18	18	600
15	51	8	43	June 5	June 6	June 11	June 25	1	6	20	20	363
16	21	9	12	June 6	June 7	June 12	June 29	1	6	23	23	428
17	35	12	23	June 7	June 9	...do.....	June 25	2	5	17	18	221
18	10	3	7	June 8	June 26	June 26	July 4	18	18	9	26	4
19	14	3	11	June 9	June 12	June 12	June 26	3	3	15	17	59
Average								2.47	5.53	19.11	20.58	......
Maximum								18	18	27	27	......
Minimum								1	2	9	11	......

Number of male moths	470
Number of female moths	696
Total number of moths	1,166
Total number of eggs	13,763
Average number of eggs per female moth	19.77

Number of eggs per female.—Of the 1,166 moths observed, 696 were females, which deposited 13,763 eggs, or an average of 19.77, which is the highest average for spring-brood moths recorded in Yakima. These data are given in Table 34.

Length of life of moths.—The average length of life of 495 male moths was 12.29 days, of 723 females 13.85 days, or 1.56 days longer than that of the males as shown in Table 35. The length of life of these moths was less by several days than the life of spring-brood moths in either 1919 or 1920.

TABLE 35.—*Length of life of male and female codling moths of the spring brood, Yakima, Wash., 1921.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of. moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
2	4	2	0	14	22	14	47	26	2	26	7
3	4	3	2	15	41	15	48	27	3	27	4
4	7	4	4	16	21	16	40	28	2	28	4
5	11	5	10	17	19	17	35	29	2	29	2
6	22	6	28	18	15	18	45	30	2	30	0
7	43	7	47	19	12	19	26	31	0	31	1
8	42	8	42	20	13	20	25	32	0	32	0
9	45	9	43	21	11	21	27	33	1	33	0
10	54	10	50	22	6	22	15	34	0	34	0
11	37	11	52	23	7	23	11	35	0	35	1
12	22	12	49	24	3	24	14				
13	19	13	39	25	3	25	5	Total.	495	Total.	723

Average length of life of male moths, 12.29 days; female moths, 13.85 days.
Maximum length of life of male moths, 33 days; female moths, 35 days.
Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

EGGS OF THE FIRST BROOD.

Time of egg deposition.—In Figure 25 is given the time of deposition of 14,822 eggs of the first brood. The first eggs were laid on May 23 and the last June 30, covering a period of over five weeks. Mean temperatures above 70° F. for the 6-hour period between 3 and 9 p. m., commencing May 29 and ending June 8, encouraged the moths to deposit 11,390 eggs, or 76.85 per cent of the total number of eggs during these 11 days. The maximum number of eggs laid in a single day was 1,379 on June 4.

Length of incubation.—Embryological studies of 7,999 eggs of the first brood show the average number of days from deposition to the appearance of the red ring to be 3.45; average number of days from deposition to the appearance of the black spot 7.6 days, and the average length of the incubation period 9.31 days. These intervals are shorter than the corresponding intervals recorded for 1919 and 1920. These data are found in Table 36.

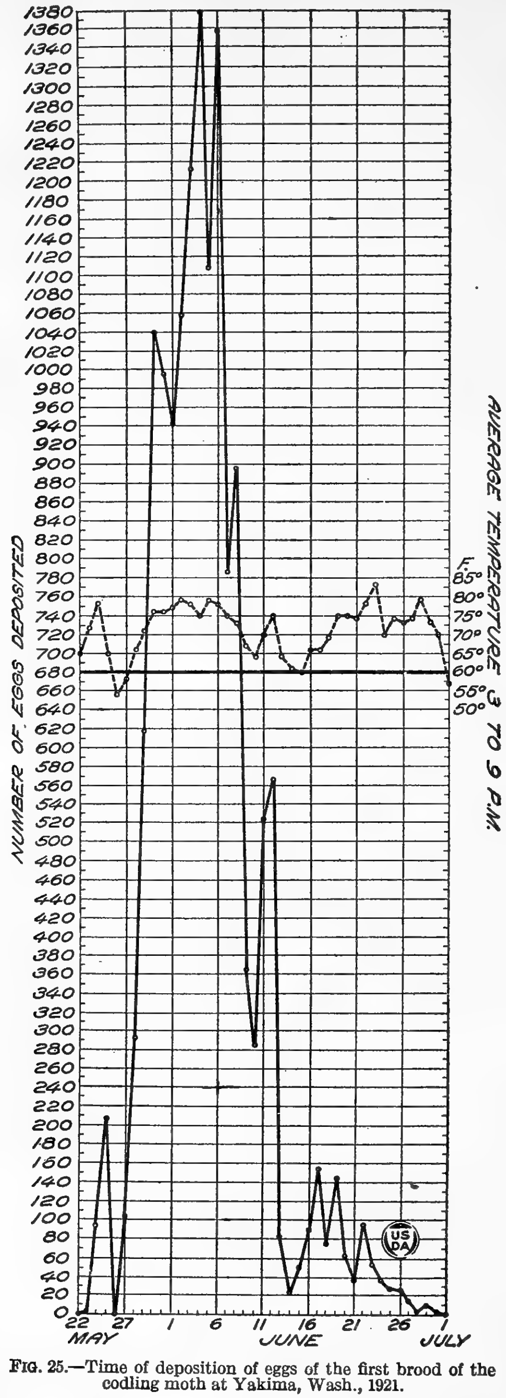

FIG. 25.—Time of deposition of eggs of the first brood of the codling moth at Yakima, Wash., 1921.

TABLE 36.—*Time of deposition and length of incubation of eggs of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
May 24	61	4.00	4	4	8.00	8	8	9.03	10	9
25	70	4.00	4	4	8.00	8	8	9.23	10	9
27	60	3.00	3	3	7.00	7	7	8.08	9	8
28	80	3.00	3	3	6.00	6	6	7.19	9	7
29	258	3.00	3	3	6.00	6	6	7.40	8	7
30	497	3.00	3	3	6.00	6	6	7.28	8	7
31	585	3.00	3	3	6.00	6	6	7.27	8	7
June 1	608	3.00	3	3	6.00	6	6	7.02	8	7
2	640	3.00	3	3	6.00	6	6	7.43	8	7
3	690	3.00	3	3	6.00	6	6	8.82	10	8
4	738	3.00	3	3	7.00	7	7	9.52	10	9
5	525	3.00	3	3	7.00	7	7	9.85	10	9
6	462	3.00	3	3	9.00	9	9	10.00	10	10
7	505	4.00	4	4	11.00	11	11	12.20	13	12
8	702	4.00	4	4	10.00	10	10	12.31	13	12
9	228	5.00	5	5	11.00	11	11	12.24	13	12
10	112	5.00	5	5	11.00	11	11	12.29	13	12
11	225	4.00	4	4	10.00	10	10	11.29	12	11
12	292	4.00	4	4	10.00	10	10	11.00	11	11
13	58	7.00	7	7	9.00	9	9	10.45	11	10
14	13	7.00	7	7	9.00	9	9	10.31	11	10
15	43	6.00	6	6	8.00	8	8	9.51	11	9
16	73	6.00	6	6	7.00	7	7	8.64	9	8
17	75	5.00	5	5	7.00	7	7	8.83	9	8
18	73	5.00	5	5	6.00	6	6	8.00	8	8
19	107	4.00	4	4	6.00	6	6	7.98	9	7
20	36	4.00	4	4	7.00	7	7	8.19	9	8
21	28	3.00	3	3	7.00	7	7	8.14	9	8
22	41	3.00	3	3	7.00	7	7	8.00	8	8
23	49	3.00	3	3	7.00	7	7	9.27	10	8
24	12	3.00	3	3	8.00	8	8	9.25	10	9
25	16	3.00	3	3	8.00	8	8	9.31	10	9
26	16	3.00	3	3	8.00	8	8	9.00	9	9
27	14	3.00	3	3	8.00	8	8	9.14	10	9
28	3	5.00	5	5	8.00	8	8	9.00	9	9
29	4	4.00	4	4	8.00	8	8	9.75	11	9
	7,999	3.45	7	3	7.60	11	6	9.31	13	7

LARVÆ OF THE FIRST BROOD.

Time of hatching.—The time of hatching of larvæ of the first brood was quite regular with the exception of June 17 and 18. Mean temperatures below 60° F. on June 14 and 15 so delayed the development of the eggs that no hatching occurred on June 17 and 18. The first larvæ hatched on June 2, and the last on July 10, with a

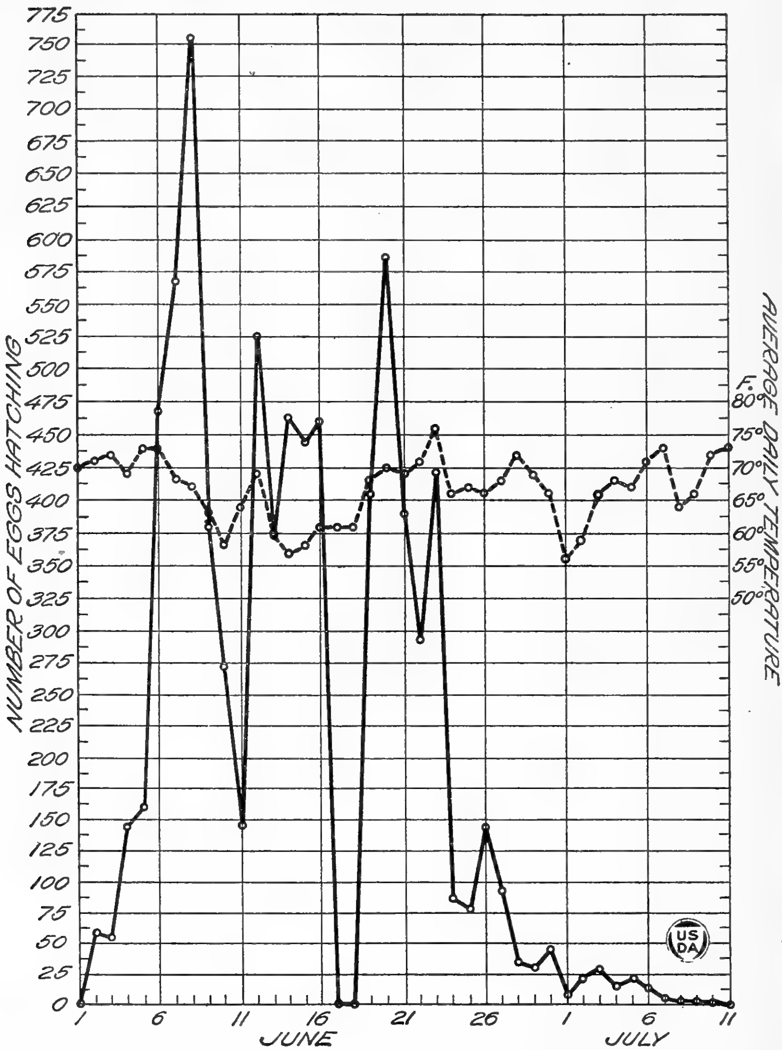

FIG. 26.—Hatching of larvæ of the first brood of the codling moth at Yakima, Wash., 1921.

maximum of 755 on June 8. (See fig. 26.) Larvæ of the first brood were thus hatching over a period of 39 days.

Length of the feeding period.—In Table 37 the length of the feeding period of 722 first-brood larvæ is tabulated. These data include both transforming and nontransforming larvæ.

TABLE 37.—*Length of feeding period of larvæ of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 2	2	31.00	34	28	June 22	71	23.99	29	13
3	3	27.33	31	24	23	74	24.54	33	20
4	6	28.67	31	25	24	24	24.54	32	20
5	4	27.75	30	25	25	46	24.48	37	18
8	12	34.33	44	26	26	18	24.78	30	19
9	24	31.38	38	18	27	27	24.89	32	22
10	19	32.53	36	30	28	15	21.80	24	19
11	28	30.25	44	22	29	6	21.33	27	15
12	13	28.77	38	24	30	4	22.50	24	22
13	24	28.08	32	24	July 1	9	22.11	33	13
14	39	26.97	39	19	2	7	22.14	25	20
15	31	30.32	42	25	4	6	22.17	26	19
17	10	27.20	36	22	5	1	18.00	18	18
18	24	27.46	34	24	6	2	21.50	22	21
19	36	25.89	33	21	7	4	21.75	25	20
20	54	24.46	33	20	8	1	17.00	17	17
21	78	23.35	29	12					

Total number of larvæ	722
Average length of feeding period in days	25.83
Maximum length of feeding period in days	44
Minimum length of feeding period in days	12

Length of the cocooning period.—The average number of days which 540 larvæ of the first brood required to build their cocoons was 6.12. The date of leaving the fruit and the average, maximum, and minimum length of the cocooning period of these larvæ are given in Table 38

TABLE 38.—*Length of cocooning period of transforming codling moth larvæ of the first brood, Yakima, Wash., 1921.*

Larvæ left fruit.	Number of larvæ.	Cocooning period in days.			Larvæ left fruit.	Number of larvæ.	Cocooning period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
June 27	2	8.00	8	8	July 15	49	6.37	15	2
29	1	7.00	7	7	16	55	6.76	21	3
30	3	6.00	6	6	17	43	7.40	23	2
July 2	4	6.00	10	4	18	38	5.50	13	4
3	6	8.00	10	5	19	22	6.77	24	2
4	6	5.50	6	5	20	17	5.41	12	3
5	3	6.00	7	5	21	16	4.94	11	1
6	2	5.50	6	5	22	21	5.00	16	2
7	12	5.17	11	4	23	11	6.18	19	2
8	8	5.00	10	4	24	7	8.29	28	4
9	15	4.53	7	4	25	3	9.67	21	3
10	19	5.37	16	3	26	3	4.33	5	4
11	28	6.36	20	3	27	2	3.50	4	3
12	40	5.50	14	4	28	2	14.00	24	4
13	43	6.16	16	3	29	2	15.50	23	8
14	56	5.71	14	3	30	1	6.00	6	6

Total number of larvæ	540
Average length of cocooning period in days	6.12
Maximum length of cocooning period in days	28
Minimum length of cocooning period in days	1

PUPÆ OF THE FIRST BROOD.

Time of pupation.—Pupation by larvæ of the first brood was first observed on July 5 and continued daily, with four exceptions, until August 15. This is shown in Figure 27, which also gives the date of maximum pupation as July 23, when 52 larvæ transformed.

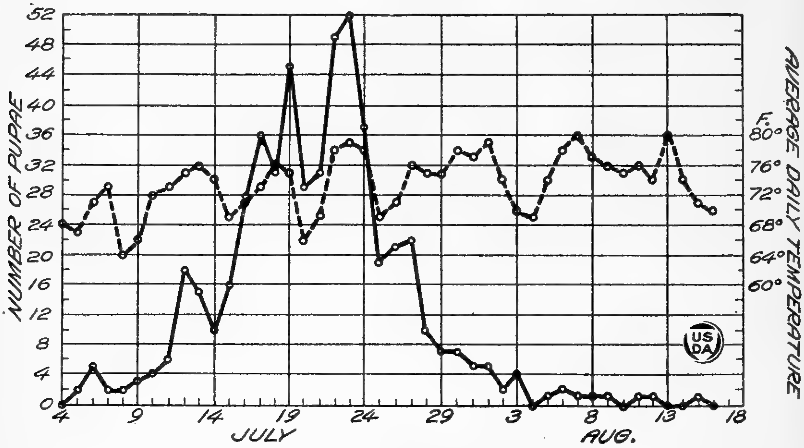

FIG. 27.—Pupation of the first brood of the codling moth at Yakima, Wash., 1921.

Length of pupal stage.—Table 39 shows the length of the pupal stage of 491 pupæ.

TABLE 39.—*Length of the pupal stage of pupæ of the first brood of the codling moth, Yakima, Wash., 1921.*

Date of pupation.	Number of pupæ.	Pupal period in days. Average.	Maximum.	Minimum.	Date of pupation.	Number of pupæ.	Pupal period in days. Average.	Maximum.	Minimum.
July 5	2	11.00	11	11	July 24	33	12.36	14	10
6	5	12.80	14	12	25	16	11.88	14	10
7	2	14.50	15	14	26	18	12.89	25	11
8	1	11.00	11	11	27	22	12.32	13	10
9	3	13.00	14	12	28	9	11.89	14	10
10	3	13.00	13	13	29	8	12.50	14	11
11	6	12.67	17	11	30	6	11.67	13	9
12	17	13.18	16	11	31	6	11.83	13	10
13	14	12.14	14	11	Aug. 1	4	12.50	14	12
14	10	12.70	14	12	2	2	11.50	12	11
15	13	12.62	18	11	3	5	12.20	16	10
16	26	13.62	27	10	5	1	11.00	11	11
17	32	13.00	20	11	6	1	14.00	14	14
18	24	12.75	20	9	7	1	13.00	13	13
19	43	12.77	27	6	8	1	17 00	17	17
20	28	12.21	14	11	9	1	12.00	12	12
21	30	12.20	13	11	12	1	16.00	16	16
22	45	11.89	15	6	21	3	23.00	24	22
23	49	12.78	26	10					

Total number of pupæ	491
Average length of pupal stage in days	12.62
Maximum length of pupal stage in days	27
Minimum length of pupal stage in days	6

MOTHS OF THE FIRST BROOD.

Time of emergence.—Moths emerged in the insectary from July 13 to October 9, inclusive, a longer period than heretofore observed. These moths include individuals emerging from material reared in the insectary, and from larvæ collected under bands in the field. Three individuals emerging on September 5, 6, and 7 from insectary-bred material are second-brood moths, and it is assumed that some second-brood moths are included in the moths emerging from field collections. Moths emerged in large numbers for about a month, beginning July 21, with the maximum of 78 on July 31. Figure 28 graphically indicates these data.

Oviposition by moths of the first brood.—The oviposition records of 46 cages in which were confined 645 female moths are given in Table 40. Eggs were laid one day after emergence in 20 of the cages.

Number of eggs per female moth.—Table 40 gives the data on the deposition of 13,154 eggs by 645 females of the first brood, which emerged between July 21 and August 30. This is an average of 20.39 eggs.

TABLE 40.—*Oviposition by codling moths of the first brood in rearing cages, Yakima, Wash., 1921.*

Observation.	Number of moths.	Sex.		Date of—				Number of days—				Total number of eggs deposited.
		Male.	Female.	Emergence.	First oviposition.	Maximum oviposition.	Last oviposition.	Before oviposition.	From emergence to maximum oviposition.	Of oviposition.	From emergence to last oviposition.	
1	20	6	14	July 22	July 23	July 24	Aug. 1	1	2	10	10	211
2	14	9	5	July 23	July 25	July 25	Aug. 3	2	2	10	11	274
3	21	7	14	July 24	...do....	July 27	Aug. 6	1	3	13	13	550
4	32	9	23	July 25	July 26	July 29	Aug. 15	1	4	21	21	330
5	31	12	19	July 26	July 27	July 30	Aug. 8	1	4	13	13	237
6	20	7	13	July 27	July 29	July 29	Aug. 7	2	2	10	11	147
7	38	16	22	July 28	...do....	July 31	Aug. 11	1	3	14	14	646
8	35	12	23	July 29	July 30	July 31	Aug. 12	1	2	14	14	390
9	40	17	23	July 30	July 31	Aug. 1	Aug. 8	1	2	9	9	320
10	79	29	50	July 31	Aug. 1	Aug. 2	Aug. 13	1	2	13	13	1,141
11	55	19	36	Aug. 1	Aug. 2	Aug. 4	Aug. 16	1	3	15	15	992
12	54	13	41	Aug. 2	Aug. 3	Aug. 7	Aug. 15	1	5	13	13	757
13	74	26	48	Aug. 3	Aug. 4	Aug. 6	Aug. 14	1	3	11	11	764
14	20	5	15	Aug. 4	Aug. 6	Aug. 7	Aug. 11	2	3	6	7	356
15	70	22	48	Aug. 5	...do....	...do....	Aug. 20	1	2	15	15	1,666
16	63	23	40	Aug. 6	Aug. 8	Aug. 8	Aug. 23	2	2	16	17	715
17	35	13	22	Aug. 7	...do....	Aug. 10	Aug. 19	1	3	12	12	421
18	40	11	29	Aug. 8	Aug. 9	Aug. 13	Aug. 26	1	5	18	18	307
19	36	12	24	Aug. 9	Aug. 12	Aug. 14	...do....	3	5	15	17	507
20	18	9	9	Aug. 10	...do....	Aug. 19	Aug. 23	2	9	12	13	59
21	26	9	17	Aug. 11	...do....	Aug. 15	Aug. 27	1	4	16	16	269
22	18	5	13	Aug. 12	Aug. 14	Aug. 14	Aug. 23	2	2	10	11	186
23	30	9	21	Aug. 13	...do....	Aug. 15	Sept. 1	1	2	19	19	234
24	9	4	5	Aug. 14	Aug. 15	...do....	Sept. 2	1	1	19	19	114
25	24	10	14	Aug. 15	Aug. 18	Aug. 23	...do....	3	8	16	18	232
26	15	5	10	Aug. 16	...do....	Aug. 22	Aug. 30	2	6	13	14	135
27	5	2	3	Aug. 17	Aug. 20	...do....	Aug. 27	3	5	8	10	65
28	13	5	8	Aug. 18	Aug. 19	Aug. 20	Aug. 31	1	2	13	13	95
29	16	9	7	Aug. 19	Aug. 20	Aug. 25	Sept. 7	1	6	19	19	414
30	15	4	11	Aug. 20	Aug. 23	Aug. 24	Sept. 5	3	4	14	16	99
31	15	9	6	Aug. 21	Aug. 25	Aug. 30	Sept. 9	4	9	16	19	296
32	5	4	1	Aug. 22	Aug. 29	Aug. 29	Aug. 29	7	7	1	7	2
33	8	5	3	Aug. 28	...do....	Aug. 30	Sept. 26	1	2	29	29	104
34	10	2	8	Aug. 29	Aug. 31	Sept. 3	Sept. 7	2	5	8	9	119
Average								1.74	3.79	13.56	14.29	....
Maximum								7	9	29	29	....
Minimum								1	2	1	7	....

Number of male moths	359
Number of female moths	645
Total number of moths	1,004
Total number of eggs	13,154
Average number of eggs per female moth	20.39

Length of life of moths.—Table 41 shows that the average length of life of 356 male moths of the first brood was 11.72 days; of 643 females, 11.39 days.

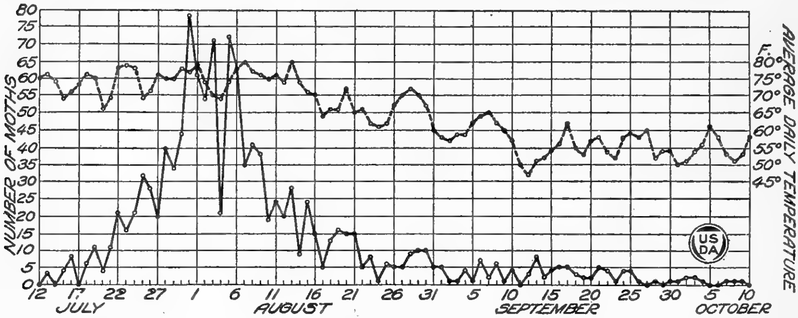

FIG. 28.—Emergence of the first and second broods of moths of the codling moth at Yakima, Wash., 1921.

TABLE 41.—*Length of life of male and female codling moths of the first brood, Yakima, Wash., 1921.*

Male.		Female.		Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	
1	3	1	3	14	19	14	35	26	1	26	2
2	1	2	1	15	17	15	23	27	1	27	1
3	4	3	10	16	16	16	28	28	2	28	1
4	18	4	22	17	9	17	31	29	1	29	0
5	14	5	21	18	5	18	12	30	1	30	0
6	21	6	44	19	11	19	20	34	1	34	1
7	36	7	65	20	5	20	8	35	1	35	0
8	20	8	37	21	12	21	6	37	1	37	0
9	24	9	49	22	4	22	6	39	1	39	0
10	33	10	68	23	2	23	4	50	0	50	1
11	29	11	46	24	2	24	3				
12	21	12	44	25	2	25	7	Total..	356	Total.	643
13	18	13	44								

Average length of life of male moths, 11.72 days; female moths, 11.39 days.
Maximum length of life of male moths, 39 days; female moths, 50 days.
Minimum length of life of male moths, 1 day; female moths, 1 day.

LIFE CYCLE OF THE FIRST GENERATION.

Table 42 shows the periods in the life of 490 individuals of the first generation from the time of deposition of the egg to the emergence of the adult. From this table the average life cycle is found to be 54.14 days, to which must be added 1.74 days, the average length of the preoviposition period, to give the complete life cycle from egg to egg, which in this case is 55.88 days. All larvæ were brought through the feeding period by the stock-jar method.

TABLE 42.—*Life cycle of the first generation of the codling moth as observed by rearing, stock-jar feeding method, Yakima, Wash., 1921.*

Date of egg deposition.	Number of individuals.	Incubation.	Larval feeding period. Average.	Larval feeding period. Maximum.	Larval feeding period. Minimum.	Cocooning period. Average.	Cocooning period. Maximum.	Cocooning period. Minimum.	Pupal period. Average.	Pupal period. Maximum.	Pupal period. Minimum.	Life cycle.[1] Average.	Life cycle.[1] Maximum.	Life cycle.[1] Minimum.
			Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
May 24	2	9	31.00	34	28	5.50	6	5	12.50	13	12	58.00	60	56
25	3	9	27.33	31	24	6.67	8	6	12.33	13	11	55.33	59	52
27	5	8	28.20	30	25	5.40	7	5	13.40	15	12	55.00	57	52
29	3	7	27.00	28	25	5.00	6	4	13.00	14	12	52.00	54	50
June 1	8	7	32.13	38	26	6.25	11	3	12.38	13	11	57.76	64	52
2	17	7	30.18	38	18	7.88	16	3	12.53	16	11	57.59	60	44
2	11	8	32.36	36	30	7.45	16	4	12.73	14	10	60.54	69	54
3	18	8	28.83	34	22	5.44	9	4	13.17	18	12	55.44	60	51
3	9	9	28.00	30	24	4.78	6	4	14.00	27	11	55.78	70	50
4	15	9	27.27	32	24	4.93	8	3	12.33	16	9	53.53	61	50
4	30	10	26.23	30	19	5.10	16	3	12.63	17	11	53.97	68	45
5	11	10	29.18	39	25	9.18	28	3	13.45	23	10	61.82	100	51
6	4	11	24.75	31	22	4.75	6	4	13.50	14	13	54.00	61	50
6	12	12	26.33	30	24	7.08	12	4	13.42	18	11	58.83	64	52
7	30	12	25.67	31	21	6.07	18	2	12.53	20	10	56.27	72	49
8	34	12	24.47	33	20	6.91	18	3	12.26	14	10	55.65	68	46
9	59	12	23.90	29	19	6.05	23	2	12.90	20	10	54.85	73	45
10	60	12	23.80	29	13	6.58	24	3	12.72	25	10	55.10	79	42
12	51	11	24.35	31	20	5.82	14	4	12.69	26	10	53.86	61	47
15	15	9	23.73	32	20	5.60	17	3	12.20	14	11	50.53	61	46
16	33	9	23.61	29	18	5.61	20	3	12.61	27	10	50.82	70	42
18	10	8	23.70	29	19	5.70	16	1	11.60	13	10	49.00	63	43
19	18	8	24.56	32	22	5.39	11	3	12.00	14	10	49.95	62	45
20	7	8	20.71	22	19	4.29	5	4	11.29	13	10	44.29	47	42
21	5	8	20.60	27	15	4.20	6	3	10.60	12	6	43.40	51	34
22	4	8	22.50	24	22	4.00	4	4	11.00	11	11	45.50	47	45
23	6	8	20.33	28	13	6.83	23	2	12.50	22	7	47.66	81	33
23	4	9	22.25	25	21	4.25	5	3	11.75	14	11	47.25	49	46
25	1	9	26.00	26	26	6.00	6	6	11.00	11	11	52.00	52	52
26	1	9	18.00	18	18	4.00	4	4	12.00	12	12	43.00	43	43
27	2	9	21.50	22	21	14.00	24	4	18.00	24	12	62.50	79	46
28	1	9	21.00	21	21	4.00	4	4	12.00	12	12	46.00	46	46
29	1	9	17.00	17	17	5.00	5	5	9.00	9	9	40.00	40	40
	490	10.22	25.23	39	13	6.07	28	1	12.62	27	6	54.14	100	33

[1] Add 1.74 days for complete life cycle.

THE SECOND GENERATION.

EGGS OF THE SECOND BROOD.

Time of deposition.—The complete period over which the first brood of moths laid eggs extended over the 91 days beginning July 15 and ending October 13, although 12,021 eggs, or 77 per cent of the total number, were deposited during the four weeks beginning

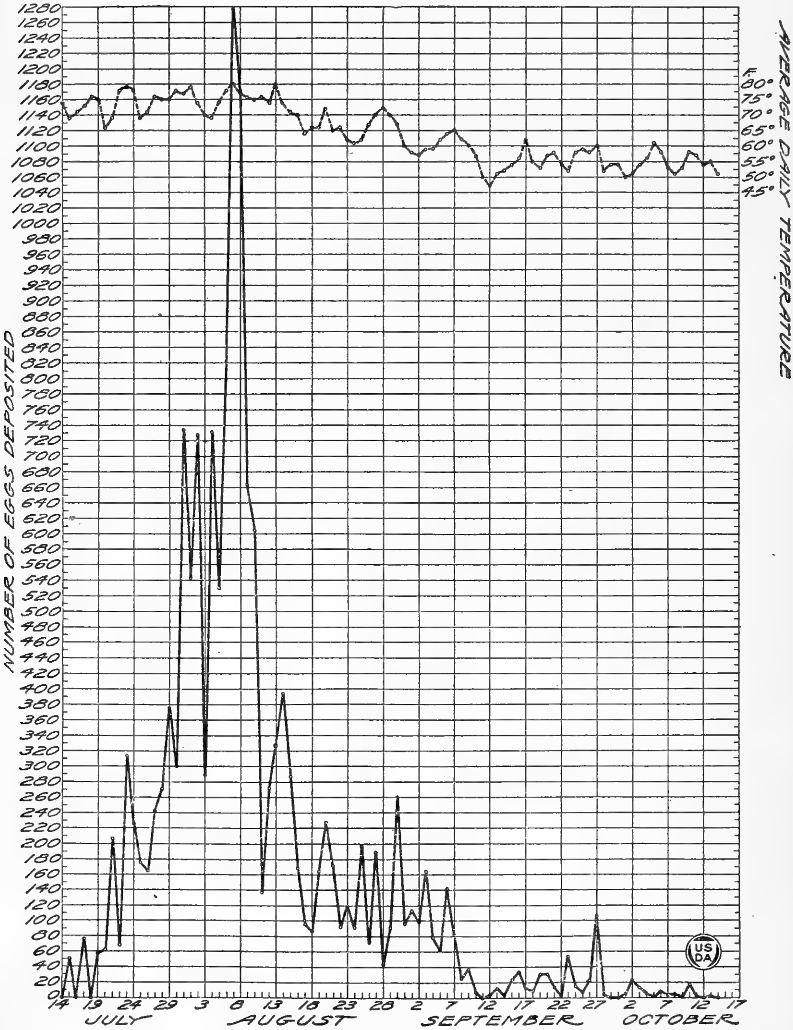

FIG. 29.—Time of deposition of eggs of the second brood of the codling moth at Yakima, Wash., 1921.

July 21 and ending August 16. The greatest number of eggs deposited in one day was 1,278 on August 7, one of the two dates on which the highest average daily temperature of the year was recorded. Figure 29 gives the time of deposition of 15,527 eggs of the second brood.

Length of incubation.—The length of the incubation period of 5,342 eggs of the second brood, the number of days from deposition to the appearance of the red ring, and the number of days from deposition to the appearance of the black spot are given in Table 43. The incubation period of eggs which were deposited after August 30 was about three times as long as required by eggs which hatched in July and early August. This is due to daily average temperatures generally below 60° F.

TABLE 43.—*Time of deposition and length of incubation of eggs of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of deposition.	Number of eggs.	Number of days from deposition to appearance of—						Incubation period in days.		
		Red ring.			Black spot.					
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
July 15	31	3.00	3	3	6.00	6	6	7.03	8	7
17	6	2.00	2	2	6.00	6	6	7.17	8	7
18	23	3.00	3	3	6.00	6	6	7.09	8	7
20	4	3.00	3	3	5.00	5	5	6.50	7	6
21	19	3.00	3	3	5.00	5	5	6.16	7	6
22	11	3.00	3	3	6.00	6	6	7.00	7	7
23	124	3.00	3	3	5.00	5	5	6.77	7	6
24	132	3.00	3	3	6.00	6	6	6.92	7	6
25	64	3.00	3	3	5.00	5	5	6.34	7	6
26	41	3.00	3	3	5.00	5	5	6.46	7	6
27	45	3.00	3	3	5.00	5	5	6.22	7	6
28	93	3.00	3	3	5.00	5	5	6.10	7	6
29	120	3.00	3	3	5.00	5	5	6.17	7	6
30	242	3.00	3	3	5.00	5	5	6.98	7	6
31	352	2.00	2	2	6.00	6	6	7.00	7	7
Aug. 1	183	2.00	2	2	5.00	5	5	6.52	7	6
2	210	2.00	2	2	6.00	6	6	7.00	7	7
3	19	2.00	2	2	5.00	5	5	6.00	6	6
4	198	2.00	2	2	5.00	5	5	6.00	6	6
5	200	2.00	2	2	5.00	5	5	6.33	7	6
6	456	2.00	2	2	5.00	5	5	6.00	6	6
7	511	3.00	3	3	5.00	5	5	6.32	8	6
8	470	2.00	2	2	5.00	5	5	6.00	6	6
9	243	2.00	2	2	5.00	5	5	6.28	7	5
10	144	2.00	2	2	5.19	6	5	6.19	7	6
11	180	2.00	2	2	6.00	6	6	7.58	8	7
12	60	2.00	2	2	6.00	6	6	8.00	8	8
13	61	2.00	2	2	7.00	7	7	8.00	8	8
14	192	3.00	3	3	7.00	7	7	9.09	10	8
15	53	3.00	3	3	7.00	7	7	9.21	10	8
16	60	3.00	3	3	8.38	9	8	10.42	12	9
17	24	3.00	3	3	8.00	8	8	10.29	11	10
18	37	3.00	3	3	8.00	8	8	9.24	10	9
19	38	3.00	3	3	8.00	8	8	9.42	10	9
20	69	3.00	3	3	8.00	8	8	9.64	10	9
21	55	3.00	3	3	8.00	8	8	9.58	10	9
22	52	3.00	3	3	8.00	8	8	9.33	11	9
23	54	3.00	3	3	8.00	8	8	10.07	11	9
24	42	3.00	3	3	8.00	8	8	10.43	11	10
25	20	3.00	3	3	8.00	8	8	11.25	13	10
26	3	4.00	4	4	9.00	9	9	11.00	11	11
27	53	4.00	4	4	9.00	9	9	11.30	12	11
29	18	4.00	4	4	10.00	10	10	16.11	17	15
30	71	4.00	4	4	14.00	14	14	17.41	18	16
31	15	6.00	6	6	15.00	15	15	17.67	19	17
Sept. 1	45	6.00	6	6	14.13	15	14	17.13	18	17
2	26	6.00	6	6	15.00	15	15	17.35	18	17
3	44	5.00	5	5	15.00	15	15	17.66	19	16
4	34	4.00	4	4	14.00	14	14	17.35	19	17
5	18	6.00	6	6	15.00	15	15	18.44	19	17
6	35	6.00	6	6	15.00	15	15	19.00	20	18
7	20	6.00	6	6	17.00	17	17	19.95	21	18
8	12	7.00	7	7	18.00	18	18	21.83	23	20
9	7	8.00	8	8	18.00	18	18	21.43	23	20
10	3	9.00	9	9	18.00	18	18	21.00	21	21
	5,342	2.64	9	2	6.23	18	5	7.70	23	5

LARVÆ OF THE SECOND BROOD.

Time of hatching.—The first larvæ of the second brood were recorded on July 22, and worms continued to hatch until October 2. The maximum number of larvæ hatching in one day was 954 on August 12, or 21 days after the earliest larvæ appeared. No worms were hatched from eggs deposited later than September 13. The time of hatching of second-brood eggs is found in Figure 30.

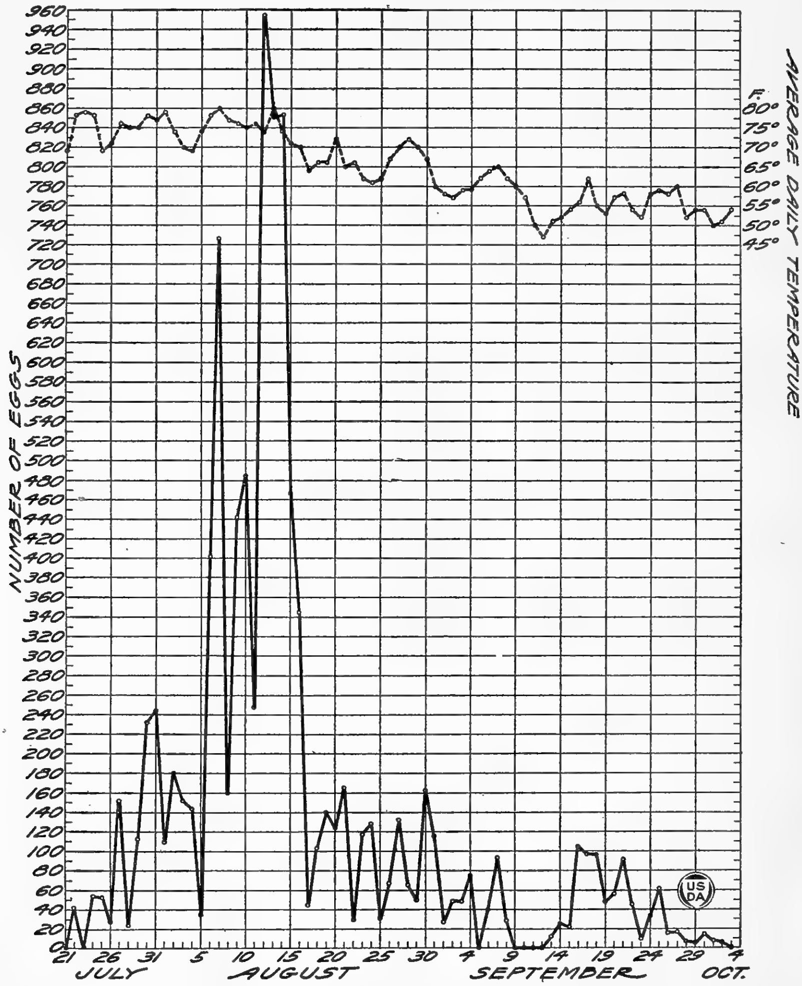

FIG. 30.—Hatching of larvæ of the second brood of the codling moth at Yakima, Wash., 1921.

Length of feeding period of wintering larvæ.—The average length of the feeding period by the stock-jar method of 559 nontransforming larvæ of the second brood was 34.02 days. The details of this period and the effect of lower temperatures from August 14 to September 19 in lengthening the feeding period are shown in Table 44.

TABLE 44.—*Length of feeding period of wintering larvæ of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of entering fruit.	Number of larvæ.	Feeding period in days.			Date of entering fruit.	Number of larvæ.	Feeding period in days.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
July 22	7	24.14	29	19	Aug. 15	30	42.96	56	29
23	1	20.00	20	20	16	14	39.93	58	31
25	5	21.40	22	20	17	11	43.00	55	28
26	1	20.00	20	20	18	12	44.58	51	34
27	6	25.50	40	21	19	6	38.17	54	17
28	3	17.67	18	17	20	9	42.11	47	33
29	11	20.64	28	18	21	7	47.00	52	42
30	20	26.65	41	20	22	15	48.80	65	39
31	14	23.71	26	20	23	6	42.83	48	38
Aug. 1	19	22.68	29	17	24	8	48.75	71	42
2	13	25.08	31	20	25	2	54.50	62	47
3	18	27.72	40	21	26	3	56.33	64	46
4	38	26.37	48	19	27	10	48.00	61	43
5	25	28.80	49	19	30	3	47.00	59	39
6	30	27.97	44	21	31	4	52.75	58	43
7	28	28.25	44	19	Sept. 1	3	63.00	72	55
8	14	27.43	36	19	2	4	63.50	70	56
9	24	27.13	40	19	3	3	60.33	71	50
10	27	30.96	54	12	4	4	63.00	66	60
11	18	32.83	49	23	6	1	61.00	61	61
12	32	35.34	48	26	7	3	58.67	61	54
13	26	36.62	60	14	15	1	56.00	56	56
14	19	39.89	61	28	19	1	39.00	39	39

Total number of larvæ	559
Average length of feeding period in days	34.02
Maximum length of feeding period in days	72
Minimum length of feeding period in days	12

Transforming larvæ of the second brood.—Five transforming second-brood larvæ which left the fruit between August 10 and August 25 had an average feeding period of 16.6 days. The average length of the cocooning period of four of these larvæ was 2.5 days. From the resulting pupæ, three female moths emerged, after passing through an average pupal period of 17.67 days. The length of the life cycle of the second brood was not computed, owing to the small number of transforming larvæ. These moths deposited 43 infertile eggs.

CODLING-MOTH BAND STUDIES OF 1921.

Band-record studies were continued in the Guthrie orchard at Yakima in 1921. Twelve of the larger trees were scraped and banded, and 3,666 larvæ were collected during the season. The first larvæ were found under bands on June 22. The last collection was made on October 14, after the fruit was harvested. Although there is some overlapping of broods in the band collections, the insectary studies indicate that August 9 may be considered the arbitrary division point between the first and second broods of larvæ. Accordingly, the maximum collection for the first brood was 149 larvæ on July 22, and for the second brood 179 larvæ on August 30.

The results of these studies are given in Figure 31.

No band-record studies were made in the Walden orchard in 1921.

A summary of the seasonal history of the codling moth for 1921 is shown in Figure 32.

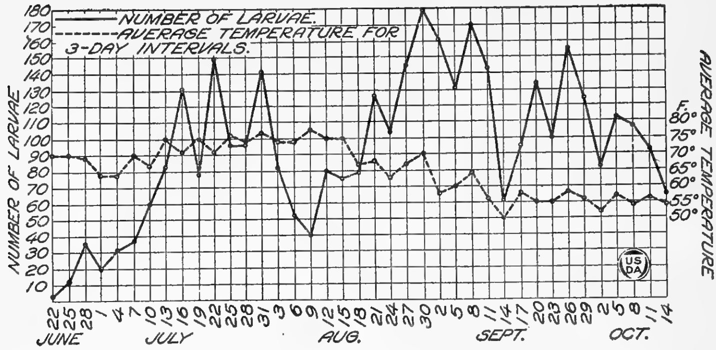

FIG. 31.—Occurrence of codling moth larvæ under bands on apple trees at Yakima, Wash., 1921.

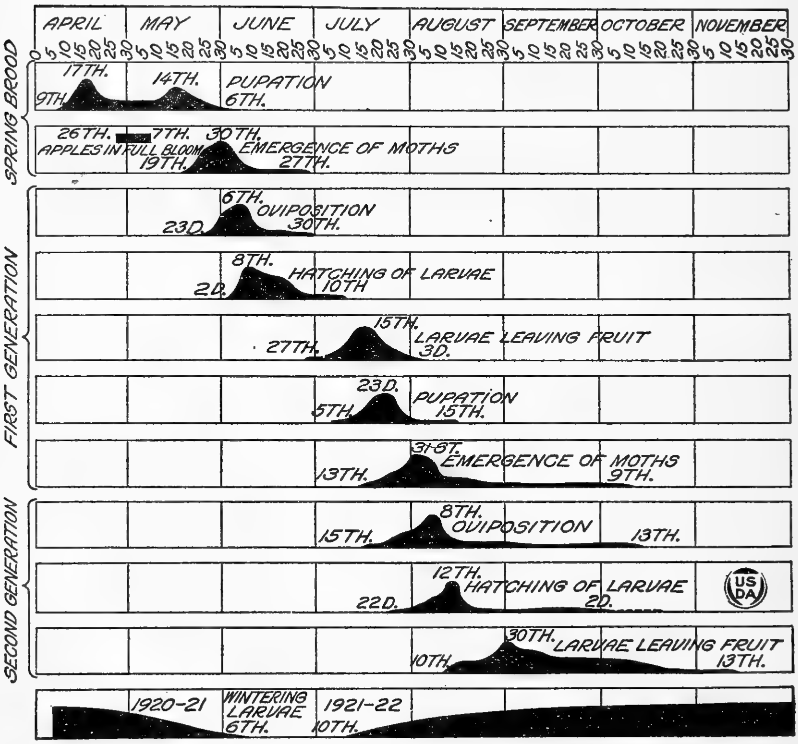

FIG. 32.—Seasonal history of the codling moth at Yakima, Wash., 1921.

VARIATIONS IN THE SEASONAL HISTORY OF THE CODLING MOTH IN THE UPPER AND LOWER YAKIMA VALLEYS.

Owing to the fact that the Yakima Valley is divided into two large sections, the upper and the lower valleys, and that the season in the lower valley is somewhat earlier than in the upper, some studies were made by means of banded trees and screen cages to ascertain the effect this difference would have on the seasonal history of the codling moth.

In Figure 33 a comparison is made between band records secured in 1919 at Yakima in the upper valley, and at Buena in the lower valley (see also p. 20). The solid line is a record of the occurrence of larvæ under bands at Yakima, with an elevation of 1,100 feet, and the dotted line records the same thing for Buena, with an elevation of 850 feet, the two stations being approximately 16 miles apart. At Buena the maximum number of first-brood larvæ occurred July 3, and at Yakima a high point was reached July 17, which, judging from insectary records, probably represents the true maximum more accurately than the high point of August 1. Thus there was an interval

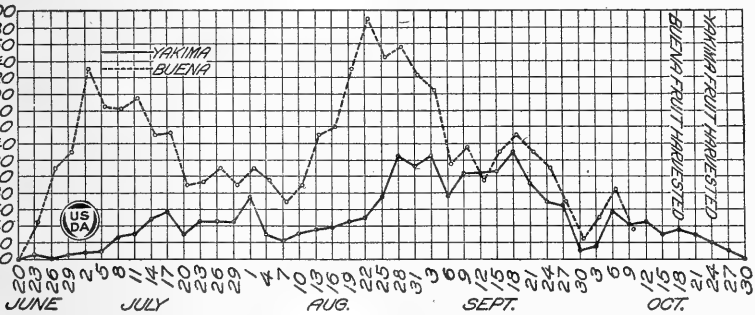

FIG. 33.—Occurrence of codling moth larvæ under bands on apple trees at two points in the Yakima Valley, Wash., 1919.

of 14 days between the two stations. For the second brood the maximum at Buena occurred August 23. At Yakima the actual maximum occurred September 18, 26 days later, but this was due to an accumulation of larvæ delayed by cold weather occurring September 8 to 13, and it is believed that the true maximum should have been about September 3, or 11 days later than at Buena.

In 1920 not enough larvæ were secured at Buena to show conclusively when the maximum for the broods occurred, but the apparent maximum at Buena occurred several days before that at Yakima.

Temperature records were kept in the orchard at Buena in 1920 and 1921 with a thermograph, and a comparison of these with similar orchard records at Yakima shows that the average monthly temperature at Buena is higher than that at Yakima. The average difference in 1920 and 1921 for each month during which records were taken has been figured and was as follows: April, 4.7°; May, 3°; June, 3.1°; July, 2.4°; August, 2.3°; September, 2.4°; the average for the season being 3°.

Screen cages containing from 50 to 200 larvæ were also placed at various points in both valleys in 1920, 1921, and 1922 and examined

every three days during the time the spring brood of moths were emerging. These cages were stocked with larvæ in the fall, the larvæ being allowed to spin cocoons under a burlap band around a section of a tree limb held upright in the center of the cage. The cages were placed in the crotches of trees in orchards early in March, before any development had taken place. They were thus kept under as nearly normal conditions as possible. The elevation at these stations ranged from 800 to 2,000 feet. These cages differed very little in the time of emergence of moths. At most of the stations the maximum emergence occurred within three days of the maximum date at the insectary at Yakima. Thus in 1920 the maximum date at Yakima was June 2. Of 13 cages, the maximum emergence occurred in 10 of them during the period from June 1 to June 4, inclusive. Of the other three cages, one was in the lower valley on a south slope, and the maximum occurred May 21, and the other two were at elevations 600 and 1,000 feet higher than Yakima, and the maximum emergence occurred on June 8 and June 15, respectively. In 1921 the maximum emergence at the insectary and in a cage in the experimental orchard occurred on May 30. In the other nine cages it occurred from three to nine days later. In 1922 maximum emergence of moths again occurred at most stations within a few days of the maximum at the insectary at Yakima. The maximum at Yakima was on June 1. In the lower valley two stations were maintained and the maximum occurred at one of them on May 27, and at the other on May 30. In the upper valley the maximum at two stations was May 30; at five, June 2; and at one, with an elevation of 2,000 feet, June 8. This evidence tends to show that there is not very much difference between different parts of the two valleys in the time of emergence of moths of the spring brood, though, owing to the warmer summer weather in the lower valley, the majority of the first brood of larvæ became full-grown from a week to two weeks earlier than in the upper valley.

SEASONAL-HISTORY STUDIES AT WENATCHEE, WASH., 1915 AND 1916.

During the seasons of 1915 and 1916 the senior author, while stationed in the Wenatchee Valley of Washington, undertook some life-history studies of the codling moth. Since these were carried on as a minor project, it was not possible to make as detailed studies as have been made at Yakima, but it is deemed advisable to present here a summary of the data that were obtained in order that a comparison may be drawn between the two districts.

The Wenatchee Valley is situated in central Washington, about 60 miles north of Yakima. The elevation at Wenatchee, which is just south of the confluence of the Wenatchee and Columbia Rivers, is only about 800 feet, but as the valley is nearer the Cascade Mountains than the Yakima Valley the season is about the same. The average apple crop in the Wenatchee district is about the same as that of the Yakima district.

The winter of 1914–15 was mild and the spring early. Maximum temperatures of 80° F. or more were experienced on April 16 to 19, inclusive, which is unusual for this month. Warm weather was again experienced during the first week in May, after which temperatures

were somewhat below normal, and the precipitation was relatively heavy. The early part of June was cool, but the rest of the summer was unusually warm. Of the 72 days in the period from June 21 to August 31, inclusive, 38 days had maximum temperatures of 90° F. or over. The apple trees were in full bloom April 15 to 20.

Figure 34 gives a summary of the stages in the life history of the codling moth that were chiefly studied in 1915. The maximum pupation occurred during the warm weather in April and the maximum emergence of spring-brood moths just one month later. Of 144 pupæ observed, the average pupal period was 30.44 days.

No further studies of the codling moth were made until late in June. Newly hatched larvæ had been first noted entering the fruit on trees in the laboratory yard on May 29, and on June 27 the mature larvæ were beginning to leave the fruit. On this date 226 wormy apples were collected to secure material for further observations.

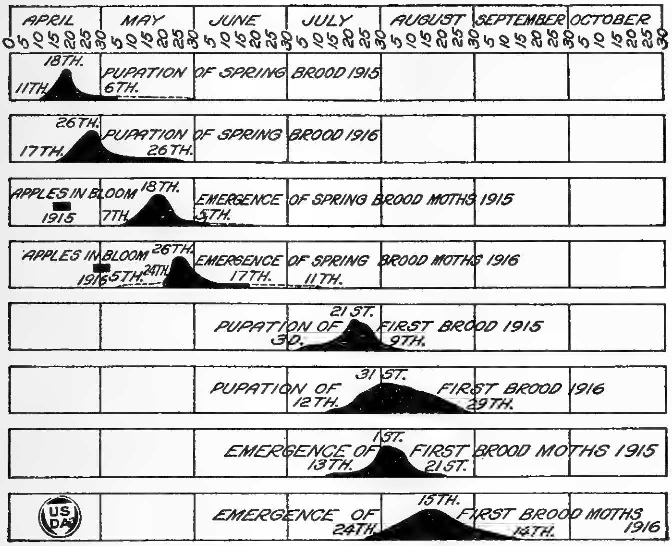

FIG. 34.—Partial seasonal history of the codling moth at Wenatchee, Wash., 1915 and 1916.

Of the 179 first-brood larvæ observed, the average cocooning period was 6.82 days. Pupation began July 3, as shown in Figure 34, and continued until August 9, with a maximum on July 21. The average pupal period of these first-brood individuals was 11.87 days. Moths began emerging from them on July 13 and continued until August 21, with a maximum on August 1.

Larvæ of the second generation began leaving the fruit on August 24, reached a maximum on September 4, and continued to leave the fruit until October 6. No evidence of a third generation was obtained.

In 1916, the season was later than in 1915, but little warm weather being experienced until the second week in June, when it suddenly became hot, temperatures going above 90° F. on June 13 to 17 inclusive, and above 100° F. on the last two days of this period. This hot weather was followed by two weeks of abnormally cool,

rainy weather. Thereafter the weather was not unusually warm until the last week in August, when temperatures of 100° F. or more were again experienced for five or six days. With a cooler spring, the development of trees was delayed, and apples were not in full bloom until about the beginning of May, nearly two weeks later than in 1915.

Figure 34 summarizes the data secured on several of the stages of the codling moth in 1916. Pupation was at a maximum on April 26, and the average length of the pupal stage was 31.29 days. Moths of the spring brood began emerging in the orchards early in May, though none was secured at the insectary from the limited material available until May 20. There was a maximum emergence on May 24, and emergence continued until June 17, though, owing to the cool weather of the latter part of June, a few moths emerged in the orchards as late as July 11. Only general observations were made on oviposition, and this work began late in May and continued as long as moths were present.

Larvæ of the first brood began leaving the fruit on July 5. On July 11 an examination was made of 687 wormy apples, and it was found that the mature larvæ had gone from 5.6 per cent of these. The largest number left the fruit on August 3, and larvæ continued to leave until August 24. The average cocooning period for 493 first-brood larvæ was 6.42 days. Pupation occurred from July 12 until August 29, with a maximum on July 31, as shown in Figure 34. The average pupal period of 493 first-brood pupæ was 13.49 days.

Moths of the first brood were emerging from July 24 until September 14, and probably later, with a maximum on August 15, and the oviposition followed very closely the emergence of the moths. The maximum hatching of second-brood larvæ occurred August 15 to 20.

It will be seen from this brief summary that the life history of the codling moth in the Wenatchee Valley follows very closely that in the Yakima Valley, but each period would probably occur slightly later in the same year at Wenatchee than at Yakima.

MISCELLANEOUS STUDIES.

WINTERKILLING OF LARVÆ.

It is a common occurrence to find winterkilled codling moth larvæ when examining trees in the spring. Some larvæ appear to succumb to fewer degrees of cold than others, but, as the cold increases, increasing numbers of larvæ are killed. An opportunity of studying this effect of the cold was afforded in the winter of 1919–1920. In December, 1919, minimum temperatures were experienced in the Yakima Valley lower than any previously recorded. On December 9 and 10, a severe snowstorm occurred, with some wind. The storm cleared away on the 11th, and minimum temperatures of zero or lower were recorded for the four succeeding days. On December 13 the Weather Bureau observer at Yakima reported −24° F. while the minimum thermometer at the insectary recorded −25.5° F. Unofficial reports from various points in the Yakima Valley showed minimum temperatures of −15° to −30° F. During this cold period there were from 4 to 18 inches of snow on the ground.

After December 15, the weather gradually became warmer, and for a number of days the temperature remained above the freezing point.

All the wintering larvæ in the insectary succumbed to this extreme cold. Examinations of larvæ wintering on apple trees were made in various localities during the succeeding two months in order to ascertain the effect of different degrees of freezing on the larvæ. It was found that where minimum temperatures of $-15°$ to $-20°$ F. had been experienced from 70 to 80 per cent of the larvæ were killed. Minimum temperatures of $-20°$ to $-25°$ F. had killed from 80 to 90 per cent of the larvæ, and minimum temperatures of $-25°$ F. and lower had killed all the larvæ. In all cases the larvæ examined had no other protection than bark or burlap bands. Larvæ occurring below the snow line of December 13 or in the soil all survived, no frozen individuals being found in these places. These protected individuals made possible the continuance of the codling moth in the colder localities.

On January 18 and 19, 1922, the minimum temperature at Yakima was $-4°$ and $-8°$ F., respectively, and on several other days in January the minimum was zero. An examination of wintering larvæ on the trunks of apple trees near Yakima was made April 17. Of 346 larvæ examined, 15, or 4.3 per cent, had been frozen.

WINTERING PERIOD.

During the season of 1920, records were kept of the date of leaving fruit of all wintering larvæ, and in the spring of 1921 the dates of pupation of these larvæ were recorded. These figures show a wide variation in the length of this period. One lot of 176 larvæ collected under bands on September 18, 1920, which had all probably left the fruit within a period of three or four days, pupated over a period of 58 days in the spring of 1921, or from April 10 to June 6, inclusive, as shown in Table 45. The pupal period was more than usually prolonged in 1921, however, owing to fluctuations of temperature. A cold wave in the middle of the pupation period, from April 21 to May 4, delayed the pupation of many larvæ and resulted in two maximum periods of pupation instead of the usual one (see Fig. 23). On the other hand, there is a definite tendency of the earlier-maturing larvæ to pupate earlier than those maturing later in the fall. The pupation of 49 wintering first-brood larvæ was recorded, and of these 35, or 71 per cent, pupated during the first half of the pupation period, that is, April 9 to May 5, inclusive. Records were obtained of 499 wintering individuals of the second brood, exclusive of the lot of 176 mentioned above. As shown in Table 46, approximately half of the larvæ leaving the fruit in August pupated before May 5. Of those maturing in September, about two-thirds pupated before May 5, while of those maturing in October, only one-third pupated before May 5.

TABLE 45.—*Wintering period of codling moth larvæ of the second brood collected under bands at Yakima, Wash., September 18, 1920.*

Date of pupation	Wintering period in days	Number of individuals	Date of pupation	Wintering period in days	Number of individuals	Date of pupation	Wintering period in days	Number of individuals
1921			1921			1921		
Apr. 10	204	4	Apr. 27	221	1	May 15	239	12
11	205	5	May 1	225	1	16	240	6
12	206	3	2	226	1	17	241	4
14	208	1	4	228	1	18	242	4
15	209	2	5	229	3	19	243	5
16	210	5	6	230	6	20	244	5
17	211	8	7	231	4	21	245	2
18	212	8	8	232	5	22	246	7
19	213	3	9	233	7	23	247	4
20	214	2	10	234	5	24	248	3
21	215	7	11	235	5	29	253	1
22	216	3	12	236	8	June 4	259	2
25	219	3	13	237	5	6	261	1
26	220	2	14	238	12			
							....	176

Average number of days in wintering period........ 229.79
Maximum number of days in wintering period........ 261
Minimum number of days in wintering period........ 204

TABLE 46.—*Time of pupation of wintering larvæ of the second brood of the codling moth, Yakima, Wash., 1921.*

Date of leaving fruit.	Number of individuals.	Date of pupation. April 9 to May 5, 1921. Number.	Per cent.	May 6 to June 5, 1921. Number.	Per cent.
Aug. 22–31	39	18	46	21	54
Sept. 1–15	201	135	67	66	33
Sept. 16–30	140	92	66	48	34
Oct. 1–15	75	26	35	49	65
Oct. 16–30	44	14	32	30	68
Total	499	285	57	214	43

EMERGENCE OF MOTHS FROM THE SOIL.

In the Yakima Valley a considerable number of wintering codling-moth larvæ spin their cocoons in the soil about the bases of the trees. Most of these cocoons are found in the first inch or two of soil and immediately adjacent to the trunk of the tree. (Pl. III, fig. 2.) Examinations of trash and soil away from the trunk of the tree have failed to show any appreciable number of cocoons. In the fall of 1921, five unsprayed trees were carefully examined, and 2,780 wintering larvæ were collected. Of these, 578, or 21 per cent, were in the soil.

On account of the large number of worms cocooning in the soil, it was thought desirable to ascertain what effect this fact has on the emergence of the spring brood of moths. Accordingly, in the fall of 1919, four screen cages were arranged, two of which each had an upright stump with a burlap band around it secured to the floor to simulate a banded orchard tree. The other two were each equipped with an upright piece of wood in the same position as the stump,

FIG. I.—TERMINAL SHOOT OF APPLE EXCAVATED BY LARVA

FIG. 2.—PUPAL SHELLS PROTRUDING FROM SOIL AT BASE OF APPLE TREE

HE CODLING MOTH IN THE YAKIMA VALLEY OF WASHINGTON

and several inches of soil was placed in them, about the pieces of wood, which latter were too smooth to afford a cocooning place for the worms above the soil surface (Pl. II, fig. 2). Each cage was stocked with 160 worms in September, 1919, but the extreme cold in December froze those in the band cages and some in the soil cages. Consequently, in February, 1920, 100 additional worms were placed in each band cage and 30 in each soil cage. These cages were set in the open, side by side, the soil cages being sunk in the ground so that the soil surface in the cages was level with that outside. Records of the emergence of the moths were made daily, and 60 moths were secured from the two band cages and 134 from the two soil cages.

In 1921 the experiment was repeated, 100 worms having been placed in each cage in the fall of 1920. Emergence records were kept as before, 98 moths being secured from each pair of cages. In 1922 records were again obtained, 130 moths being secured from the band cages, and 57 from the soil cages.

In Table 47 the records of the emergence of moths from the bands and from the soil are compared for the three years, the dates being given on which specified percentages of the total moths had emerged. In 1920, moths emerging from the soil appeared from 6 to 13 days later than those from the bands, while in 1921 this interval was only from 1 to 4 days. In 1922 the moths emerged from the soil cages earlier than from the others, for the most part. The reduction of the interval in 1921 was due partly, if not wholly, to a period of unseasonably warm weather occurring from May 13 to June 9, and covering practically the entire emergence period of these moths. In 1922, the weather also was unseasonably warm throughout June. Thermograph records were kept both of soil and of air temperatures, and the daily mean soil temperature every year averaged from 2 to 4° higher than the air temperature.

It is evident from these experiments that, although the soil temperature averages somewhat warmer than that of the air, the emergence of moths from the soil may be somewhat delayed and may be more prolonged than that of moths from the trunks of trees. This might be even more pronounced in orchards where cover crops shade the soil.

TABLE 47.—*Emergence of moths of the spring brood of the codling moth from bands and from the soil, Yakima, Wash., 1920, 1921, 1922.*

Per cent emerged.	1920			1921			1922		
	Date emerged.		Interval.	Date emerged.		Interval.	Date emerged.		Interval.
	From bands.	From soil.		From bands.	From soil.		From bands.	From soil.	
			Days.			*Days.*			*Days.*
1	May 10	May 16	6	May 11	May 12	1	May 17	May 16	−1
10	May 15	May 26	11	May 15	May 19	4	May 22	May 18	−4
25	May 18	May 31	13	May 20	May 23	3	May 27	May 26	−1
50	May 25	June 3	9	May 24	May 26	2	May 30	May 31	1
75	May 30	June 8	9	May 29	May 30	1	June 2	June 3	1
100	June 13	June 29	16	June 6	June 6	0	June 18	June 15	−3

TIME OF DAY MOTHS EMERGE.

In order to learn at what time of the day most of the moths emerge, observations were made on moths of both the spring brood and the first brood in 1919 and 1920. Certain lots of pupæ were observed hourly from 6 a. m. to 6 p. m., inclusive, during the time the moths were emerging in quantities, and a record was kept of the number found at each observation. The records for 6 a. m. include all moths emerging between 6 p. m. and 6 a. m.

Moths of the spring brood.—In 1919, the hourly emergence of moths was observed from May 21 to June 1, inclusive, as shown in Table 48, 454 moths being recorded. The largest number for any hour emerged between 9 and 10 a. m., 27.8 per cent of the total being recorded for this hour.

TABLE 48.—*Hourly emergence of codling moths of the spring brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1919.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
May 21	0	0	0	3	25	21	10	6	5	7	2	1	0	80
May 22	0	0	8	27	18	10	6	4	2	1	2	0	0	78
May 23	0	0	0	0	1	3	7	6	0	0	0	0	0	17
May 25	0	0	0	0	2	5	5	10	9	0	4	0	2	37
May 26	0	0	0	8	31	15	13	3	1	0	2	0	1	74
May 27	0	0	5	12	19	15	12	3	5	0	1	1	0	73
May 28	0	0	0	0	17	10	9	3	0	3	0	1	0	43
May 31	0	0	0	0	3	16	5	2	0	0	0	0	0	26
June 1	0	0	0	0	10	8	7	0	1	0	0	0	0	26
Total	0	0	13	50	126	103	74	37	23	11	11	3	3	454
Per cent	0.0	0.0	2.9	11.0	27.8	22.7	16.3	8.1	5.1	2.4	2.4	0.7	0.7	

In 1920, the hourly emergence of spring-brood moths was observed from May 26 to 31, inclusive, records being made of 284 moths. It will be seen in Table 49 that the largest number (32.0 per cent) emerged between 10 and 11 a. m. In both seasons a large majority of the moths emerged between 9 a. m. and noon, 66.8 per cent being recorded in 1919, and 65.5 per cent in 1920. In neither year did any moths emerge between 6 p. m. and 7 a. m.

TABLE 49.—*Hourly emergence of codling moths of the spring brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1920.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
May 26	0	0	0	0	3	25	25	13	5	5	0	0	0	76
May 27	0	0	0	0	20	8	4	3	9	5	3	2	0	54
May 28	0	0	0	0	3	8	2	9	8	6	3	0	0	39
May 29	0	0	0	1	2	1	2	6	1	0	0	0	0	13
May 31	0	0	0	5	19	49	15	1	2	3	4	0	4	102
Total	0	0	0	6	47	91	48	32	25	19	10	2	4	284
Per cent	0.0	0.0	0.0	2.1	16.6	32.0	16.9	11.3	8.8	6.7	3.5	0.7	1.4	

Moths of the first brood.—Hourly emergence of first-brood moths was observed in 1919 from July 21 to 23, inclusive, 138 moths being recorded. Table 50 shows that more moths emerged between 8 and 9 a. m. than during any other hour.

TABLE 50.—*Hourly emergence of codling moths of the first brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1919.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
July 21	1	1	14	13	9	4	4	3	3	4	2	0	1	59
July 22	1	1	0	13	13	11	2	3	5	1	0	0	0	50
July 23	4	0	0	4	0	8	5	1	6	1	0	0	0	29
Total	6	2	14	30	22	23	11	7	14	6	2	0	1	138
Per cent	4.3	1.5	10.1	21.7	15.9	16.7	8.0	5.1	10.1	4.3	1.4	0.0	0.7	

In 1920, observations were made from August 9 to 14, inclusive, Table 51 showing that of 234 moths the largest number emerged between 12 noon and 1 p. m. The emergence period of first-brood moths covers more hours of the day than in the case of the spring brood. In 1919, 64.4 per cent of the moths emerged between 7 a. m. and 11 a. m. In 1920, the emergence was even more prolonged, and in order to total up a comparable number of moths it is necessary to include all moths emerging between 10 a. m. and 4 p. m., between which hours 67.7 per cent of the moths emerged. In all cases, a majority of the moths emerged before the maximum temperature for the day was reached.

TABLE 51.—*Hourly emergence of codling moths of the first brood from 6 a. m. to 6 p. m., inclusive, Yakima, Wash., 1920.*

Date of emergence of moths.	Number of moths emerging at—													Total number of moths.
	A. M.							P. M.						
	6	7	8	9	10	11	12	1	2	3	4	5	6	
Aug. 9	0	0	0	1	1	2	2	11	9	4	3	0	0	33
Aug. 10	0	1	1	0	0	0	1	4	6	5	5	9	0	32
Aug. 11	2	0	0	4	1	5	2	6	0	4	1	1	0	26
Aug. 12	1	0	1	1	0	2	2	7	1	5	4	5	5	34
Aug. 13	3	0	1	2	0	6	2	11	7	6	11	4	7	60
Aug. 14	4	1	5	7	6	9	4	9	1	1	0	0	2	49
Total	10	2	8	15	8	24	13	48	24	25	24	19	14	234
Per cent	4.3	0.9	3.4	6.4	3.4	10.3	5.6	20.5	10.3	10.7	10.3	8.1	5.9	

TIME OF DAY MOTHS OVIPOSIT.

It is of some importance to know the time of day most of the codling moth eggs are deposited and the effect of varying degrees of temperature on egg deposition. It is particularly important to know the effect of temperature on the deposition of eggs by

the spring brood of moths, in order to time properly the first cover application of spray. These points were made the subjects of experiments in 1919 and 1920, both on moths of the spring brood and on those of the first brood, and in 1921 on moths of the first brood.

Moths of the spring brood.—In 1919, seven cages of moths, each containing approximately 25 individuals, were observed daily, beginning at 6 a. m., and observations were made every three hours, except at 3 a. m., during the period from June 3 to June 8, inclusive. The temperature at the time of making each observation was also noted. The results of these observations are given in Table 52, the number of eggs deposited in all the jars for any given period being added together. No eggs were deposited between midnight and 6 a. m., and thereafter the number increased for each period, reaching a maximum of 57.30 per cent of the total during the 3-hour period ending at 6 p. m. Between 3 p. m. and 9. p. m., 80.67 per cent of the total eggs were deposited.

TABLE 52.—*Time of oviposition by codling moths of the spring brood, in 3-hour periods, Yakima, Wash., 1919.*

Hour of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	June 3		June 4		June 5		June 6		June 7		June 8				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	*51*	0	*57*	0	*60*	0	*51*	0	*49*	0	*55*	0	*53.83*	0.00
9 a. m.	0	*63*	0	*67*	3	*68*	0	*59*	0	*61*	0	*65*	3	*63.83*	0.67
12 noon.	7	*72*	0	*78*	1	*79*	1	*66*	0	*67*	0	*71*	9	*72.17*	2.02
3 p. m.	24	*76*	24	*81*	4	*79*	0	*69*	2	*71*	16	*74*	70	*75.00*	15.73
6 p. m.	119	*75*	66	*79*	41	*70*	8	*62*	9	*66*	12	*69*	255	*70.17*	57.30
9 p. m.	10	*61*	76	*66*	14	*57*	0	*52*	1	*57*	3	*54*	104	*57.83*	23.37
12 midnight.	0	*58*	0	*61*	4	*56*	0	*42*	0	*51*	0	*44*	4	*52.00*	0.90
Total.	160	.....	166	.....	67	.....	9	.....	12	.....	31	.....	445	....	....

Total number of eggs on foliage 394
Total number of eggs on cages 51
Per cent of eggs on foliage 88.54

In 1920, five cages of moths were used for observations on the time of oviposition, the results of these observations being presented in Table 53. During the time these moths were under special observation they deposited no eggs between midnight and 9 a. m. Thereafter, the number increased for each succeeding 3-hour period until the period ending 6 p. m., during which 40.92 per cent of the total were deposited. Between 3 p. m. and 9 p. m., 68.97 per cent of all eggs were deposited.

Table 53.—*Time of oviposition by codling moths of the spring brood, in 3-hour periods, Yakima, Wash., 1920.*

Hours of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	June 19		June 20		June 21		June 25		June 26		June 27				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	58	0	58	0	60	0	54	0	52	0	61	0	57.17	0.00
9 a. m.	0	68	0	69	0	74	0	64	0	66	0	75	0	69.33	0.00
12 noon	2	78	0	79	0	89	8	69	10	75	0	78	20	78.00	6.60
3 p. m.	2	80	13	79	1	92	15	67	31	78	6	82	68	79.67	22.44
6 p. m.	28	77	26	73	10	81	5	61	24	78	31	81	124	75.17	40.92
9 p. m.	66	64	1	61	5	70	0	51	4	65	9	71	85	63.67	28.05
12 midnight	5	60	0	50	0	64	0	50	1	63	0	65	6	58.67	1.98
Total	103	.....	40	.....	16	.....	28	.....	70	.....	46	.....	303	....	....

Total number of eggs on foliage	246
Total number of eggs on cages	57
Per cent of eggs on foliage	81.19

These tables demonstrate that the spring brood of moths deposit a great majority of their eggs between 3 p. m. and 9 p. m. A comparison of the temperatures with the number of eggs deposited shows that very few eggs are deposited when the temperature is below 60° F. For example, in Table 53, no eggs were deposited on June 25 between 6 p. m. and 9 p. m., the temperature being 61° F. at 6 p. m. and 51° F. at 9 p. m. On the other hand, high temperatures do not necessarily cause the moths to oviposit, the maximum oviposition occurring nearly always after the maximum temperature for the day has been reached.

Moths of the first brood.—In 1919, six cages of moths were used for 3-hour oviposition records, the data secured from this study being shown in Table 54. The maximum oviposition occurred between 3 p. m. and 6 p. m., 41.20 per cent of the eggs being laid during this time, and between noon and 6 p. m., 79.27 per cent of the eggs were deposited. With one exception, no eggs were deposited between midnight and 9 a. m.

Table 54.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1919.*

Hour of observation.	Date of oviposition.														Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	July 31		Aug. 1		Aug. 2		Aug. 3		Aug. 4		Aug. 5		Aug. 6				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
a. m.	0	64	1	57	0	60	0	59	0	55	0	56	0	62	1	59.00	0.05
a. m.	0	73	0	66	0	69	0	68	0	67	0	71	0	74	0	69.71	0.00
2 noon	0	83	2	78	0	78	26	76	0	73	5	79	0	88	33	79.29	1.61
p. m.	90	88	404	83	47	81	100	74	104	73	34	83	0	91	779	81.86	38.07
p. m.	341	72	170	77	89	79	69	65	54	69	94	81	26	90	843	76.14	41.20
p. m.	36	64	30	65	48	65	6	63	1	62	89	69	157	77	367	66.43	17.94
2 mt.	4	62	0	62	1	63	0	60	0	59	3	67	15	74	23	63.86	1.12
Total	471	....	607	....	185	....	201	....	159	....	225	....	198	....	2,046	....	......

otal number of eggs on foliage	1,382
otal number of eggs on cages	664
er cent of eggs on foliage	67.55

In 1920, five cages of moths were used and, as shown in Table 55, the majority of the eggs, 54.18 per cent, were deposited between 6 p. m. and 9 p. m., and 88.47 per cent were deposited between 3 p. m. and 9 p. m.

TABLE 55.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1920.*

Hour of observation.	Date of oviposition.												Total eggs.	Average temperature.	Per cent of eggs per 3-hour period.
	Aug. 9		Aug. 10		Aug. 11		Aug. 12		Aug. 13		Aug. 14				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	*70*	0	*64*	0	*63*	0	*68*	0	*69*	0	*71*	0	*67.50*	0.00
9 a. m.	0	*77*	0	*81*	0	*80*	0	*79*	0	*81*	2	*82*	2	*80.00*	0.21
12 noon	0	*80*	2	*93*	0	*90*	6	*92*	12	*95*	4	*94*	24	*90.67*	2.54
3 p. m.	20	*80*	8	*94*	3	*91*	4	*95*	0	*99*	2	*99*	37	*93.00*	3.92
6 p. m.	51	*82*	101	*87*	75	*85*	23	*87*	35	*85*	39	*86*	324	*85.33*	34.29
9 p. m.	86	*71*	132	*76*	57	*68*	82	*71*	119	*81*	36	*82*	512	*74.83*	54.18
12 mt.	0	*73*	12	*75*	3	*72*	1	*65*	19	*80*	11	*77*	46	*73.67*	4.87
Total	157	.....	255	.....	138	.....	116	.....	185	.....	94	.....	945	....	....

Total number of eggs on foliage 676
Total number of eggs on cages 269
Per cent of eggs on foliage 71.53

In 1921, this study was again made with first-brood moths, five cages being used. As in 1920, the majority of the eggs, 54.68 per cent, were deposited between 6 p. m. and 9 p. m., and 89.35 per cent were deposited between 3 p. m. and 9 p. m. (See Table 56.)

TABLE 56.—*Time of oviposition by codling moths of the first brood, in 3-hour periods, Yakima, Wash., 1921.*

Hour of observation.	Date of oviposition.								Total eggs.	Average temperature	Per cent of eggs per 3-hour period.
	Aug. 2		Aug. 3		Aug. 4		Aug. 5				
	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.	Number of eggs.	Temperature.			
6 a. m.	0	*68*	0	*60*	0	*60*	0	*56*	0	*61.00*	0.00
9 a. m.	0	*77*	0	*71*	0	*69*	0	*70*	0	*71.75*	0.00
12 noon	0	*86*	0	*80*	8	*80*	11	*82*	19	*82.00*	1.29
3 p. m.	0	*88*	13	*82*	78	*82*	3	*86*	94	*84.50*	6.38
6 p. m.	199	*79*	67	*77*	210	*80*	35	*85*	511	*80.25*	34.67
9 p. m.	310	*70*	47	*65*	174	*67*	275	*71*	806	*68.25*	54.68
12 mt.	1	*65*	2	*61*	0	*61*	41	*69*	44	*64.00*	2.98
Total	510	......	129	......	470	......	365	......	1,474	....	....

Total number of eggs on foliage 776
Total number of eggs on cages 698
Per cent of eggs on foliage 52.65

These tables show that normally the first brood of moths deposit most of their eggs between 3 p. m. and 9 p. m., just as is the case with the spring brood of moths. It will be noted, however, that within this 6-hour period first-brood moths deposit more eggs after 6 p. m. than before, while the reverse is true of the spring brood. This is probably due to the fact that evening temperatures in August are higher than those in June. The first brood of moths of 1919 were an exception to this apparent rule, depositing more eggs between noon and 3 p. m. than between 6 p. m. and 9 p. m., and the maximum number being found at 6 p. m. instead of at 9 p. m. During the period of observation in 1919 the weather was cooler than usual, and quite windy, at least during the latter part of nearly every day. This possibly caused the moths to oviposit earlier than they would during the normal, hot, nearly windless weather which obtained at the time observations were made in 1920 and 1921.

OVIPOSITION BY INDIVIDUAL MOTHS.

In order to ascertain the number of eggs deposited by individual female codling moths, freshly emerged moths were paired and each pair placed in a cloth-covered jelly glass, containing moist sand, a sponge saturated in brown sugar solution, and fresh pear leaves, as in the other oviposition experiments. These cages were examined daily, the number of eggs recorded, and fresh leaves and sugar solution supplied.

TABLE 57.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1919.*

Pair No.	Emergence of moths.	Date of— First oviposition.	Date of— Last oviposition.	Date of— Death of female moth.	Number of days— Before oviposition.	Number of days— Of oviposition.	Number of days— From emergence to last oviposition.	Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
								Days.	*Days.*				
1	May 20	....	....	June 3	......	......	......	......	14	......	0	......	......
2	...do.....	May 24	May 24	June 7	4	1	4	14	18	1	1	1.0	1
3	May 21	May 31	June 21	June 23	10	22	31	2	33	10	86	8.6	38
4	...do.....	....	....	June 21	......	......	......	......	31	......	0	......	......
5	...do.....	....	....	June 9	......	......	......	......	19	......	0	......	......
6	...do.....	May 24	June 2	June 4	3	10	12	2	14	2	4	2.0	3
7	...do.....	....	....	June 6	......	......	......	......	16	......	0	......	......
8	May 22	....	....	June 8	......	......	......	......	17	......	0	......	......
9	...do.....	....	....	May 25	......	......	......	......	3	......	0	......	......
10	May 24	....	....	June 4	......	......	......	......	11	......	0	......	......
11	...do.....	June 4	June 11	June 12	11	8	18	1	19	5	13	2.6	7
12	...do.....	....	....	June 5	......	......	......	......	12	......	0	......	......
13	...do.....	....	....	...do.....	......	......	......	......	12	......	0	......	......
14	...do.....	June 1	June 7	June 10	8	7	14	3	17	4	13	3.3	4
15	...do.....	May 31	June 14	(1)	7	15	21	......	......	8	26	3.3	8
16	...do.....	June 2	June 7	June 14	9	6	14	7	21	5	26	5.2	11
17	May 25	...do.....	June 2	June 6	8	1	8	4	12	1	1	1.0	1
18	...do.....	....	....	June 8	......	......	......	......	14	......	0	......	......
19	...do.....	June 13	June 13	June 14	19	1	19	1	20	1	3	3.0	3
20	...do.....	....	....	June 2	......	......	......	......	8	......	0	......	......
21	...do.....	....	....	June 10	......	......	......	......	16	......	0	......	......
					......	......	......	......	......	37	173	......	......

[1] Date of death unknown.

TABLE 57.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1919*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	8.78	19	3
Number of days from emergence to last oviposition	15.67	31	4
Number of days of oviposition	7.89	22	1
Number of days on which oviposition occurred	4.11	10	1
Number of days female moth lived after last oviposition	4.25	14	1
Total length of life of female moth in days	16.35	33	3
Number of eggs deposited by one female moth	8.24	86	0
Number of eggs deposited by one female moth in one day	4.68	38	0

Moths of the spring brood, 1919.—Twenty-one pairs of spring-brood moths were segregated in 1919, and the results are given in Table 57. The average length of life of the females was 16.35 days, as compared with 16.91 for females confined in battery-jar cages (see Table 4). The average number of eggs per female in the individual jars was 8.24, while 300 females in the larger cages averaged only 6.36 eggs (see Table 3). The periods in the life of the moths in this table are not comparable with those of Table 3, which gives the data for all moths in each cage rather than for each individual moth. The largest number of eggs deposited by a female in one day was 38 and during her life 86.

No satisfactory oviposition records for individual moths were obtained in 1920.

Moths of the spring brood, 1921.—In 1921, six pairs of spring-brood moths were segregated on May 29 and May 31 each, as shown in Table 58. A comparison with Table 35 will show the average length of life of 723 females confined in battery jar cages to be 13.85 days, while the average life of 12 females confined in pairs was 14.75 days. These females laid 288 eggs, an average of 24. The female of pair No. 2 deposited 94 eggs, 47 of them being the maximum daily oviposition for a single female. The average egg deposition for the two years was 13.97 eggs per female.

TABLE 58.—*Oviposition by individual codling moths of the spring brood, Yakima, Wash., 1921.*

Pair No.	Emergence of moths.	Date of— First oviposition.	Date of— Last oviposition.	Date of— Death of female moth.	Number of days— Before oviposition.	Number of days— Of oviposition.	Number of days— From emergence to last oviposition.	Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
								Days.	*Days.*				
1	May 29	June 5	June 17	June 23	7	13	19	6	25	7	19	2.7	7
2	...do....	June 1	June 9	June 16	3	9	11	7	18	8	94	11.8	47
3	...do....	May 31	...do.....	June 14	2	10	11	5	16	8	89	11.1	44
4	...do....	June 2	June 11	June 12	4	10	13	1	14	9	55	6.1	15
5	...do....	June 7	June 22	June 23	9	16	24	1	25	3	10	3.3	7
6	...do....	June 3	June 3	June 11	5	1	5	8	13	1	1	1.0	1
7	May 31	June 6	June 6	...do.....	6	1	6	5	11	1	1	1.0	1
8	...do.....	June 8	June 8	June 10	8	1	8	2	10	1	1	1.0	1
9	...do.....	....	....	June 9	......	......	......	......	9	......	0	......	......
10	...do.....	June 4	June 8	June 12	4	5	8	4	12	2	3	1.5	2
11	...do.....	....	....	June 7	......	......	......	......	7	......	0	......	......
12	...do.....	June 3	June 8	June 17	3	6	8	9	17	5	15	3.0	6
					......	......	......	......	......	45	288	......	......

TABLE 58.—*Oviposition by individual codling moth of the spring brood, Yakima, Wash., 1921*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	5.10	9	2
Number of days from emergence to last oviposition	11.30	24	5
Number of days of oviposition	7.20	16	1
Number of days on which oviposition occurred	4.50	9	1
Number of days female moth lived after last oviposition	4.80	9	1
Total length of life of female moth in days	14.75	25	7
Number of eggs deposited by one female moth	24.00	94	0
Number of eggs deposited by one female moth in one day	6.40	47	0

Moths of the first brood, 1919.—Of the 33 female moths of the first brood segregated in pairs in jelly-glass cages in 1919, 8 of them failed to deposit eggs as shown in Table 59. However, the remaining 25 laid 988 eggs, or an average of 29.94 eggs for the 33 females. The average number of eggs per female in Table 10 is 23.39. The average length of life of the 33 females in the individual cages was 15.24 days, which is 2.15 days longer than the average found in Table 11. Table 59 also shows the maximum number of eggs per female to be 173, which is the largest number accurately recorded in these studies.

TABLE 59.—*Oviposition by individual codling moths of the first brood, Yakima, Wash., 1919.*

Pair No.	Emergence of moths.	Date of— First oviposition.	Date of— Last oviposition.	Date of— Death of female moth.	Number of days— Before oviposition.	Number of days— Of oviposition.	Number of days— From emergence to last oviposition.	Length of life of female after oviposition.	Total length of life of female moth.	Number of days on which oviposition occurred.	Total number of eggs.	Average number of eggs per oviposition.	Maximum number of eggs deposited in one day.
								Days.	Days.				
1	July 23	......	......	Aug. 2	......	......	......	......	10	......	0	......	......
2	...do....	July 25	Aug. 7	Aug. 8	2	14	15	1	16	11	91	8.3	18
3	...do....	Aug. 2	Aug. 6	Aug. 6	10	5	14	0	14	3	13	4.3	5
4	...do....	July 25	Aug. 2	Aug. 3	2	9	10	1	11	7	18	2.6	4
5	...do....	...do....	Aug. 6	Aug. 7	2	13	14	1	15	8	25	3.1	8
6	...do....	Aug. 6	Aug. 10	Aug. 11	14	5	18	1	19	5	36	7.2	28
7	July 25	...do....	Aug. 6	Aug. 7	12	1	12	1	13	1	1	1.0	1
8	...do....	July 27	...do....	...do....	2	11	12	1	13	2	3	1.5	2
9	...do....	July 30	Aug. 9	Aug. 11	5	11	15	2	17	3	14	4.7	8
10	...do....	Aug. 5	Aug. 12	Aug. 13	11	8	18	1	19	3	5	1.7	2
11	July 27	......	......	Aug. 6	......	......	......	......	10	......	0	......	......
12	...do....	July 31	Aug. 9	Aug. 13	4	10	13	4	17	3	14	4.7	12
13	...do....	......	......	Aug. 10	......	......	......	......	14	......	0	......	......
14	...do....	......	......	Aug. 12	......	......	......	......	16	......	0	......	......
15	...do....	July 30	Aug. 14	Aug. 22	3	16	18	8	26	9	29	3.2	7
16	...do....	July 29	Aug. 4	Aug. 6	2	7	8	2	10	3	5	1.7	3
17	July 28	......	......	Aug. 7	......	......	......	......	10	......	0	......	......
18	...do....	July 29	Aug. 5	Aug. 6	1	8	8	1	9	8	102	12.8	31
19	...do....	Aug. 1	Aug. 10	Aug. 12	4	10	13	2	15	6	107	17.8	44
20	...do....	July 29	July 29	...do....	1	1	1	14	15	1	1	1.0	1
21	...do....	...do....	Aug. 11	...do....	1	14	14	1	15	6	22	3.7	15
22	...do....	July 30	July 31	Aug. 10	2	2	3	10	13	2	82	41.0	78
23	July 29	Aug. 1	Aug. 8	Aug. 18	3	8	10	10	20	3	16	5.3	12
24	...do....	......	......	Aug. 6	......	......	......	......	8	......	0	......	......
25	...do....	July 30	Aug. 13	Aug. 15	1	15	15	2	17	7	81	11.6	24
26	...do....	...do....	Aug. 8	Aug. 17	1	10	10	9	19	3	4	1.3	2
27	...do....	Aug. 11	Aug. 16	Aug. 16	13	6	18	0	18	2	4	2.0	3
28	...do....	July 30	Aug. 6	Aug. 17	1	8	8	11	19	8	133	16.6	38
29	Aug. 3	Aug. 8	Aug. 15	Aug. 18	5	8	12	3	15	3	6	2.0	3
30	...do....	......	......	Aug. 22	......	......	......	......	19	......	0	......	......
31	...do....	Aug. 22	Aug. 24	Aug. 30	19	3	21	6	27	2	3	1.5	2
32	...do....	Aug. 7	Aug. 16	Aug. 17	4	10	13	1	14	9	173	19.2	71
33	...do....	......	......	Aug. 13	......	......	......	......	10	......	0	......	......
					......	......	......	......	......	118	988	......	......

TABLE 59.—*Oviposition by individual codling moths of the first brood, Yakima, Wash., 1919*—Continued.

SUMMARY.

	Average.	Maximum.	Minimum.
Number of days before oviposition	5.00	19	1
Number of days from emergence to last oviposition	12.52	21	1
Number of days of oviposition	8.52	16	1
Number of days on which oviposition occurred	4.72	11	1
Number of days female moth lived after last oviposition	4.04	14	0
Total length of life of female moth in days	15.24	27	8
Number of eggs deposited by one female moth	29.94	173	0
Number of eggs deposited by one female moth in one day	8.37	78	0

HATCHING OF THE EGG.

When the larva is ready to leave the egg it moves its head back and forth as if to stretch the eggshell. The mandibles are moved about rapidly until the point of one of them is forced through the chorion, always at some place on the periphery of the egg. An opening the size of the head is soon made in the eggshell and the larva crawls quickly out. Occasionally, a larva has been observed to kill itself in an effort to emerge from the egg by projecting the anal end first through a hole smaller than its head.

DATE OF HATCHING OF LARVÆ.

Since the time when the first, the last, and the maximum number of larvæ of each brood of the codling moth hatch and enter the fruit is the most important phase of the life-history studies in their practical application to control measures, a comparative diagram of the hatching during 1919, 1920, and 1921 is given in Figure 35. It will be noticed that the hatching curves for the first brood are entirely unlike, and that the first larvæ in 1919 hatched 5 days later than the first larvæ in 1921, and the first in 1920, 6 days later than the first in 1919. The maximum hatching in 1921 occurred only 7 days after the first hatching, and this was 10 days earlier than the date of maximum hatching in 1919, and 20 days before that of 1920.

The hatching curves of the second brood are much more alike than those of the first brood, and the dates of the first and maximum hatching are nearly the same. It will be noticed that the dates of the first hatching in 1919 and 1921 are identical, and that for 1920 is 11 days later. The date of maximum hatching in 1920 is also identical with that in 1921, in spite of the difference of 11 days in the date of hatching of the first larvæ, and the date of maximum hatching of second-brood larvæ in 1919 is but 5 days earlier. Figure 35 shows the necessity of accurate life-history data wherever efficient and economical control is to be obtained.

HABITS OF NEWLY-HATCHED LARVÆ.

Directly upon emerging from the egg the young larvæ seek food, which in the case of the codling moth is preferably the fruit of the apple or pear. Occasionally they will burrow into the veins and stems of leaves, and even into the terminal twigs (as shown in Pl. III, fig. 1). However, of about 250 newly-hatched larvæ which

were placed on the terminal twigs of a small apple tree, only two developed to half their normal size before they died.

Before attacking the fruit, the larva will crawl about for several minutes seeking a suitable place to enter. It prefers the calyx cup, stem cavity, or an injury to the skin, as these places afford protection and ease of entrance. When beginning to feed, the larva removes the pubescence on the surface of the apple and cuts into the skin, using its mandibles with a circular motion of the head similar to the action of an auger. The greater part of the skin which is cut away is piled beside the hole, though a little is eaten. Larvæ entering apples dipped in a red stain showed the stained particles very clearly in their digestive systems soon after feeding began. When a hole the size of the head is cut through the skin,

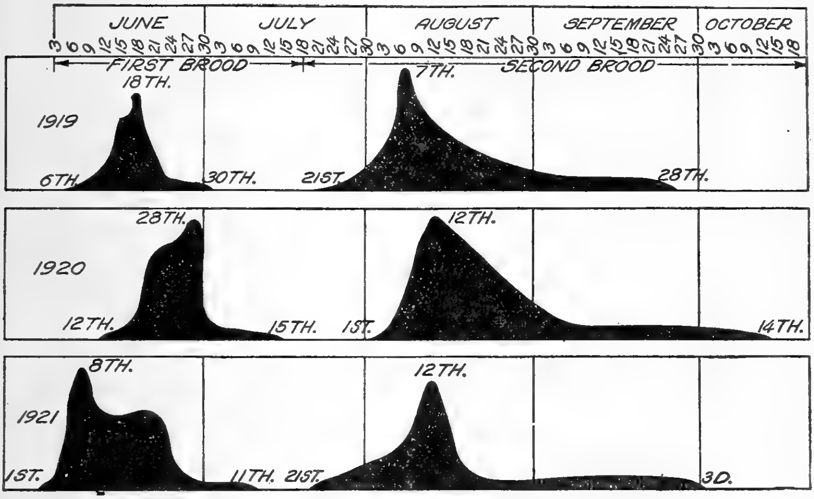

FIG. 35.—Time of hatching of codling moth larvæ, Yakima, Wash.

the larva excavates a cell large enough to contain its body, and enters, at the same time pulling over the entrance of the burrow the frass which it has laid aside and held in place with silk. This process requires about 1½ hours.

PERCENTAGE OF TRANSFORMING AND WINTERING LARVÆ.

In Table 60, it is shown that 84.97 per cent of the first brood of larvæ transformed the same season in 1919, 76.80 per cent in 1920, and 82.78 per cent in 1921. In both 1919 and 1921, 6 larvæ of the second brood transformed the same year, being 1.42 per cent and 1.02 per cent, respectively, of the total larvæ, while in 1920 only one second-brood larva, 0.21 per cent of the total, transformed. In 1919, 15.03 per cent of the first brood of larvæ did not transform until the following spring, in 1920 the percentage was 23.20, and in 1921 it was 17.22. Practically all of the second brood of larvæ pass the winter in cocoons, the percentages being 98.58 in 1919, 99.79 in 1920, and 98.98 in 1921.

TABLE 60.—*Percentage of transforming and wintering codling moth larvæ, Yakima, Wash., 1919, 1920, and 1921.*

Year.	Brood.	Number of larvæ—			Per cent transforming.	Per cent wintering.
		Leaving fruit.	Transforming.	Wintering.		
1919	First	173	147	26	84.97	15.03
	Second	423	6	417	1.42	98.58
1920	First	306	235	71	76.80	23.20
	Second	485	1	484	.21	99.79
1921	First	662	548	114	82.78	17.22
	Second	589	6	583	1.02	98.98

NATURAL ENEMIES OF THE CODLING MOTH.

Natural enemies of the codling moth are conspicuously absent in the Yakima Valley. While collecting larvæ from bands, evidences of attack by predacious insects were occasionally observed, and carabid beetles were numerous about the trees, but no beetles were noticed in the act of killing larvæ.

In October, 1919, at Buena, Wash., a small number of codling-moth eggs on harvested apples were found to be infested with a parasite, which upon emergence proved to be *Trichogramma minutum* Riley. This is the only instance of parasitism observed in these studies.

In 1914, at Wenatchee, Wash., the senior author collected from cocoons of the codling moth a specimen of an ichneumonid parasite, which was determined by R. A. Cushman, of the Bureau of Entomology, to be *Aenoplex plesiotypus* Cush. In 1916, at Wenatchee, two specimens of *Aenoplex plesiotypus* and one specimen of another ichneumonid parasite, *Epiurus indagator* Walsh, also determined by R. A. Cushman, were reared from codling-moth cocoons by the senior author.

Because of the absence of natural enemies of the codling moth in the Yakima Valley, several hundred codling-moth larvæ parasitized by *Ascogaster carpocapsae* Vier. and *Bassus carpocapsae* Cush. were sent to this laboratory from Dover, Del., by E. R. Selkregg, from Cornelia, Ga., by E. R. Van Leeuwen, and from Sandusky, Ohio, by G. A. Runner, all of the Bureau of Entomology. Many of these succumbed during the extreme cold of December, 1919, and no results were obtained the following year. In 1921 a large number of these parasites were reared and liberated, and evidences of parasitism were observed in several codling-moth larvæ collected under bands in August and September. In June, 1922, two specimens of *Bassus carpocapsae* were reared from this material, showing that this species is becoming established. These attempts to introduce hymenopterous parasites of the codling moth will be continued.

REVIEW OF SEASONAL HISTORY OF THE CODLING MOTH IN 1919, 1920, AND 1921.

The seasonal history of the codling moth in the Yakima Valley for 1919, 1920, and 1921 is given graphically in Figures 11, 22, and 32. Each curve shows approximately the occurrence of one stage in the development of the insect. A comparison of the seasonal history for the three seasons is given in Table 61.

TABLE 61.—*Comparison of seasonal history of the codling moth, Yakima, Wash., 1919, 1920, and 1921.*

Stage and year.	Date of—		
	First.	Maximum.	Last.
Pupation of spring brood:			
1919	Apr. 8	Apr. 27	May 26
1920	Apr. 3	Apr. 26	May 17
1921	Apr. 9	Apr. 17	June 6
Emergence of spring-brood moths:			
1919	May 13	May 21	June 19
1920	May 10	June 2	July 2
1921	May 19	May 30	June 27
Deposition of first-brood eggs:			
1919	May 21	June 4	June 24
1920	May 12	June 18	July 11
1921	May 23	June 4	June 30
Hatching of first-brood eggs:			
1919	June 7	June 18	June 29
1920	June 12	June 28	July 14
1921	June 2	June 8	July 10
First-brood larvæ leaving fruit:			
1919	June 23	July 12	July 31
1920	July 6	July 18	Aug. 16
1921	June 22	July 14	Aug. 3
Pupation of first-brood larvæ:			
1919	July 7	July 19	Aug. 12
1920	July 10	July 17	Aug. 15
1921	July 5	July 23	Aug. 15
Emergence of first-brood moths:			
1919	July 8	July 19	Sept. 24
1920	July 23	Aug. 15	Sept. 30
1921	July 13	July 31	Oct. 9
Deposition of second-brood eggs:			
1919	July 15	July 29	Sept. 20
1920	July 27	Aug. 7	Oct. 10
1921	July 15	Aug. 7	Oct. 13
Hatching of second-brood eggs:			
1919	July 22	Aug. 7	Sept. 27
1920	Aug. 2	Aug. 12	Oct. 13
1921	July 22	Aug. 12	Oct. 2
Second-brood larvæ leaving fruit:			
1919	Aug. 13	Sept. 3	Oct. 28
1920	Aug. 19	Sept. 4	Nov. 2
1921	Aug. 10	Sept. 5	Nov. 13

SUMMARY.

The seasonal-history studies recorded in this bulletin were made in the Yakima Valley of Washington during the years 1919, 1920, and 1921.

The codling moth, while not as serious a pest in Washington as it is in some other States, is the most serious and widespread insect pest with which the Washington apple growers have to deal. The climatic conditions are such that two practically complete generations occur, with a very small third generation in some seasons, as evidenced by the data herein.

A comparative summary of the length of the various periods in the life cycle of the codling moth at Yakima in 1919, 1920, and 1921, is given in Table 62. The figures in this table are taken from the individual tables and not from the combined life-cycle tables for each year.

TABLE 62.—*Summary of the average length of the different periods in the life cycle of the codling moth, Yakima, Wash., 1919, 1920, 1921.*

Season.	Spring brood.		First generation.						Second generation.				
	Pupal period.	Preoviposition period.	Incubation period.	Feeding period.[1]	Cocooning period.	Pupal period.	Preoviposition period.	Life cycle.	Incubation period.	Feeding period (transforming larvæ).[1]	Cocooning period.	Pupal period.	Feeding period (wintering larvæ).[1]
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1919	31.63	5.53	12.73	23.82	6.99	13.91	1.63	58.42	8.72	21.80	7.20	16.00	34.51
1920	33.56	6.87	10.60	19.05	5.48	12.37	2.93	48.01	8.74	......	......	......	35.30
1921	29.53	2.47	9.31	25.83	6.12	12.62	1.74	55.88	7.70	16.60	2.50	17.67	34.02
Grand average	31.57	4.96	10.88	22.90	6.20	12.97	2.10	54.10	8.39	19.20	4.85	16.84	34.61

[1] Stock-jar method.

The various phases in the life of the adult codling moths for the three seasons are compared in Table 63.

TABLE 63.—*Summary of the phases in the life of the adult codling moth, Yakima, Wash., 1919–1921.*

Phase and year.	Minimum.	Average.	Maximum.
Number of days before oviposition by spring-brood moths:			
1919	1	5.53	18
1920	1	6.83	22
1921	1	2.47	18
Number of days before maximum oviposition by spring-brood moths:			
1919	3	9.93	18
1920	3	12.45	23
1921	2	5.53	18
Number of days of oviposition by spring-brood moths:			
1919	2	14.67	24
1920	1	15.03	27
1921	9	19.11	27
Number of days from emergence to last oviposition by spring-brood moths:			
1919	8	19.20	28
1920	9	20.70	34
1921	11	20.58	27
Number of eggs per female moth of the spring brood:			
1919	1	6.36	86
1920	......	6.71	......
1921	1	19.77	94
Length of life of male moths of the spring brood:			
1919	1	15.33	28
1920	2	16.65	43
1921	2	12.29	33
Length of life of female moths of the spring brood:			
1919	2	16.91	29
1920	2	17.73	45
1921	2	13.85	35
Number of days before oviposition by first-brood moths:			
1919	1	1.63	4
1920	1	2.93	14
1921	1	1.74	7
Number of days before maximum oviposition by first-brood moths:			
1919	1	4.21	14
1920	1	5.55	18
1921	2	3.79	9
Number of days of oviposition by first-brood moths:			
1919	9	14.95	24
1920	5	15.70	26
1921	1	13.56	29
Number of days from emergence to last oviposition by first-brood moths:			
1919	9	15.58	26
1920	9	17.64	29
1921	7	14.29	29

TABLE 63.—*Summary of the phases in the life of the adult codling moth, Yakima, Wash., 1919–1921*—Continued.

Phase and year.	Minimum.	Average.	Maximum.
Number of eggs per female moth of the first brood:			
1919	1	23.39	173
1920		21.96	
1921		20.39	
Length of life of male moths of the first brood:			
1919	2	13.97	45
1920	2	13.87	34
1921	1	11.72	39
Length of life of female moths of the first brood:			
1919	1	13.08	37
1920	1	13.24	40
1921	1	11.39	50

Studies of certain phases of the seasonal history of the codling moth in the upper and lower Yakima Valleys indicate that the spring brood of moths appears in both valleys at about the same time, but that the majority of the mature larvæ of the first brood are leaving the apples from a week to two weeks earlier in the lower valley.

Incomplete seasonal history data recorded at Wenatchee, Wash., in 1915 and 1916 indicate that the life cycle of the codling moth is approximately the same at Wenatchee as at Yakima.

A winter temperature of $-25°$ F. or colder may kill all the codling moth larvæ above snow line, a temperature of $-20°$ to $-25°$ F. may kill 80 to 90 per cent of the larvæ, a temperature of $-15°$ to $-20°$ F. may kill 70 to 80 per cent, while a temperature of only $-7°$ or $-8°$ F. kills only about 4 per cent of the wintering larvæ.

Moths of the spring brood emerging from cocoons spun in the soil may appear from 1 to 9 days later than those from cocoons above ground, although in 1922 they appeared earlier on the average.

Most of the moths of the spring brood emerge in the morning, two-thirds of them appearing between 9 a. m. and noon. Moths of the first brood emerge over a longer period of the day, but the majority of them appear before the maximum temperature for the day is reached.

Female moths of the spring brood deposit 65 to 80 per cent of their eggs between the hours of 3 p. m. and 9 p. m., most of these being deposited before 6 p. m. Very few eggs are deposited unless the temperature is 60° F. or higher. Female moths of the first brood also deposit a great majority of their eggs between 3 p. m. and 9 p. m., but owing to the higher temperatures most of these eggs are deposited after 6 p. m.

From oviposition records obtained from individual female moths of the spring brood it appears that the moths may lay as many as 94 eggs, while others will lay none, the average being 14. Moths of the first brood deposit twice as many eggs, the number ranging from none to 173, with an average of 30.

The codling moth larva emerges from the egg through an opening made in the periphery, never through the portion of the eggshell adhering to the fruit or leaf.

The date of hatching of the earliest larvæ of the first brood varied as much as 11 days in the three years the codling moth was under

observation in the Yakima Valley, and the date of maximum hatching varied 20 days. The date of earliest hatching of the second brood of larvæ also varied 11 days, while the date of maximum hatching varied only 5 days.

Newly hatched larvæ, after finding an apple or pear, will crawl about over it for some time before entering it. It requires an hour or more for the larva to hide itself in the fruit, and most of the skin is bitten off in small pieces and not eaten. If a larva fails to find a fruit, it may burrow into the midrib of a leaf or a terminal shoot, but it appears to be unable to maintain itself on this food.

From 75 to 85 per cent of the first brood of larvæ, and from less than 1 per cent to nearly 2 per cent of the second brood of larvæ transform the same season, the others waiting until the following year.

The egg parasite *Trichogramma minutum* Riley has been observed in the Yakima Valley, and the larval parasites *Aenoplex plesiotypus* Cush. and *Epiurus indagator* Walsh were observed at Wenatchee. Occasional evidence of predators was observed.

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August 14, 1924.

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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Connecticut Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1238

Washington, D. C. ▼ October 15, 1924

THE CANKERWORMS

By

B. A. PORTER, Entomologist, and
C. H. ALDEN, Scientific Assistant, Fruit Insect Investigations,
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CONTENTS

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THE CANKERWORMS.[1]

By B. A. PORTER, *Entomologist*, and C. H. ALDEN, *Scientific Assistant, Fruit Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

The fall cankerworm (*Alsophila pometaria* Harris) and the spring cankerworm (*Paleacrita vernata* Peck) have been known in New England for more than two centuries, and in the Mississippi Valley for three-quarters of a century. The studies which form the basis of this bulletin were carried on at the laboratory maintained by the Bureau of Entomology at Wallingford, Conn., in cooperation with the Connecticut Agricultural Experiment Station at New Haven, for the study of insects affecting deciduous fruit trees. With the exception of one small isolated orchard which was badly infested with the spring cankerworm until the owners commenced spraying, neither species has been seriously abundant in the vicinity of Wallingford the past few years, although both were present in fair numbers.

The two species have much in common, and wherever possible they have been treated together.

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[1] The work upon which this bulletin is based was done under the direction of Dr. A. L. Quaintance. The life-history work in connection with the spring species was carried on largely by the junior author; that on the fall form, for the most part by the senior author.

ECONOMIC HISTORY.

The cankerworms are among our oldest native pests, the record of their ravages beginning in colonial days. As early as 1661, one John Hull is said to have written that they had been abundant for four years. For the succeeding century and a quarter the record is very fragmentary, but, beginning with an outbreak occurring about 1790, it is possible to trace the successive outbreaks in considerable detail, although the accounts are often obscured by a lack of accurate information as to the identity of the species involved, and by accounts of local outbreaks occurring independently of the main fluctuations.

Among the premiums offered in 1793 by the Massachusetts Society for Promoting Agriculture were the following (*1*)[2]:

1. To the person who shall, on or before the first day of July, 1795, give a satisfactory natural history of the canker worm, through all of its transformations, at what depth in the ground, at what distance from the tree, and at what time they cover themselves; at what season, and in what form they rise from the ground; on what part of the tree they generally deposit their eggs, and at what time the eggs become worms; a premium of 50 dollars, or a piece of plate of that value, or the Society's gold medal, at the option of the author. If more than one satisfactory history should be given before the first of July, 1795, that first received by the Trustees will be entitled to the premium.
2. A premium of 100 dollars, to the person who shall, on or before the first day of July, 1796, discover an effectual, and the cheapest method of destroying the canker worm, and give evidence thereof to the satisfaction of the Trustees.

The first premium was secured in 1795 by William D. Peck (*2*), who described in considerable detail the life history and appearance of the different stages, chiefly of what we now know as the spring cankerworm, giving it the name *Phalaena vernata*. He noted, however, that some of the moths "rise" in November, doubtless referring to the fall species, although his figures were apparently all drawn from the spring form. A lesser prize was awarded to Noah Atwater (*3*), who also presented a good account of this pest. Peck's article was reprinted with some slight changes in 1796 in the Rules and Regulations of the Massachusetts Society for Promoting Agriculture (*4*). Parts of it have been reprinted a number of times since.

Before Peck's account appeared, the cankerworms had practically disappeared from New England, this being attributed to a freeze occurring in May, 1794, shortly after the larvæ had hatched. In 1801, the trustees (*5, p. 4*) of the Massachusetts society announced that "inasmuch as the cankerworm has in some places made its appearance again, it is judged proper to continue the premium for the most effectual and cheap method for its destruction." This outbreak was apparently not as severe as the previous one, because in the Agricultural Repository and Journal for June, 1815, J. Lowell (*6*) writes: "After having been freed for nearly twenty years from the ravages of the cankerworm * * * our orchards are again overrun with them." In this account, he says that the "insects rise in the fall," indicating that this particular outbreak consisted, to a great extent at least, of the fall species.

According to records made by Harris (*10*), the cankerworms were increasingly abundant in Massachusetts from 1831 to 1840, were not troublesome for the following six years, and were again on the increase from 1847 to 1854. Since that time numerous outbreaks have

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[2] Reference is made by number (italic) to "Literature cited," p. 36.

occurred at intervals in various parts of New England. In Connecticut, the "cankerworm years" have occurred during the following periods: 1838–1846, 1866, 1884, 1896–1900, and 1907–1909. The fall cankerworm seems to be on the increase at the present time (1921) in the State, although it is impossible to predict when the infestation will become severe enough to constitute an outbreak.

The history of the cankerworms in other sections of the country has been similar in many ways to that recorded for New England, consisting of successive outbreaks varying in extent and severity, alternating with periods of comparative scarcity.

In the Middle West, practically all records refer to the spring species. The history of the cankerworm in this section begins in 1852, with an outbreak in Illinois, which lasted from that date until 1860, in which year the worms suddenly disappeared. Severe outbreaks of the spring cankerworm have been reported at intervals in practically all States of the Mississippi Valley from Arkansas north.

Kansas has suffered outbreaks of the spring cankerworm during the periods 1879–1886, 1896–1899, and 1913–1917.

Both species have been known for many years in southern Canada, the fall form being most abundant and widespread, but the infestations in most cases do not seem to have been as severe as many of those occurring in the Mississippi Valley and in New England. The fall cankerworm has done considerable damage in Nova Scotia in recent years.

Neglected orchards in northern Virginia were badly infested by the spring species for several years previous to 1907 (*32*).

The fall cankerworm was reported from California in 1891, and later the spring species was also found. Since that time several outbreaks have occurred, and considerable damage has been done in the apple-growing regions of the central and northern parts of the State.

Local outbreaks of the fall species have been in progress in forest areas in the mountains of North Carolina since 1917, and a serious infestation of both species, the spring cankerworm especially, was reported from Wisconsin in 1921.

SCIENTIFIC HISTORY.

As already noted, the name given to "the" cankerworm by Peck in 1795 was *Phalaena vernata*, his description applying almost entirely to the spring form. In several accounts published between 1830 and 1841, the cankerworms were mentioned by Harris and others as *Geometra vernata*. In 1841, in his Report on the Insects of Massachusetts Injurious to Vegetation, Harris (*9, p. 333*) placed them in the genus Anisopteryx. At the same time he noted that two types of moths were found, and suggested that there might be two species involved. Should this be the case, he said, the latter may be called *Anisopteryx pometaria*, or the Anisopteryx of the orchard, while the former should retain the name originally given to it by Professor Peck.

More than 30 years elapsed before the existence of two species was generally recognized.

In 1862, Francis Walker (*11*) described two American species of Anisopteryx which he called *sericeiferata* and *restituens*. These

were later (*26*) shown to be synonyms of *vernata* Peck and *pometaria* Harris, respectively.

The two species were clearly distinguished in 1873, when Mann (*15*) indicated the differences between the adults of the two species, but owing to a lack of clearness in the language which had been used by Harris, he reversed the intended application of the specific names, calling the fall species *vernata* and the spring form *pometaria*. His attention was soon called to the error, and in a communication published January 1, 1874 (*16*), he corrected it, giving the specific names to the respective forms as we know them to-day. He also distributed a correction slip to be inserted with the original account. The following year, in his annual report for 1874, Riley (*17*) carried the distinction still further, differentiating between the two species in all stages, and illustrating the differences by figures. The same year he erected a new genus for *vernata* (*18*), and since that time the spring cankerworm has been generally known as *Paleacrita vernata* (Peck). In spite of the efforts made by Mann to correct his error, and in spite of the publication of Riley's account, the confusion caused by the misinterpretation of the language used by Harris persisted for several years, and in 1876 Packard (*19*) suggested for the fall species the name *autumnata* to replace *pometaria* Harris, which he thought had been applied by Harris to the spring species. This change was soon shown to be unnecessary.

The species *pometaria* was placed in the genus Alsophila by Hulst (*27*) in 1896, and since then no change has been made in nomenclature.

In 1901, Dyar (*29*) published detailed technical descriptions of the egg and larval stages of the fall cankerworm, and in 1902 (*30*) he published similar descriptions of the spring species.

SYNONYMY.

Paleacrita vernata (Peck).

Phalaena vernata Peck, 1795, *in* Mass. Mag., v. 7, Nos. 6 and 7, p. 323–327, 415–416.

Geometra vernata (Peck) Harris, 1830, *in* New England Farmer, v. 9, No. 1, p. 1–2.

Anisopteryx vernata (Peck) Harris, 1841, *in* Harris, Injurious Ins. Mass., p. 333.

Anisopteryx sericeiferata Walker, 1862, *in* Cat. Brit. Mus., pt. 26, p. 1697.

Paleacrita vernata (Peck) Riley, 1785, *in* Trans. Acad. Sci. St. Louis, v. 3, p. 573–577.

Alsophila pometaria (Harris).

Anisopteryx pometaria Harris, 1841, Injurious Ins. Mass., p. 333.

Anixopteryx restituens Walker, 1862, *in* Cat. Brit. Mus., pt. 26, p. 1696.

Alsophila pometaria (Harris) Hulst, *in* 1896, Trans. Amer. Ent. Soc., v. 23, Hayden), v. 10, p. 400.

Alsophila pometaria (Harris) Hulst, 1896, *in* Trans. Amer. Ent. Soc., v. 23, p. 257–258.

COMMON NAMES.

Cankerworms belong to that group of lepidopterous larvæ variously known as inchworms, measuring worms, spanworms, or loopers. The name cankerworm originated several centuries ago, and was used in Europe for a number of different species of caterpillars. In America the term cankerworm has been used for the most part in reference to the two species here discussed, although

it has been used to a limited extent for other species belonging to the same group. In recent years the two common species have been known respectively as the fall cankerworm (*Alsophila pometaria*) and the spring cankerworm (*Paleacrita vernata*), referring to their respective seasons of usual emergence.

DIFFERENCES BETWEEN THE SPECIES.

Table 1 gives briefly the most conspicuous differences by which the two species may be distinguished in all stages.

TABLE 1.—*Distinguishing characteristics of the fall and spring cankerworms.*

Stage.	Fall cankerworm.	Spring cankerworm.
Egg	Brownish gray, in the form of a flowerpot, laid in a compact, single-layered mass in exposed locations, chiefly in the fall.	Dull pearl, oval in shape, laid in loose clusters in protected places, almost exclusively in the spring.
Larva	A pair of rudimentary prolegs on the 5th abdominal segment.	No prolegs on the 5th abdominal segment.
Pupa	Enclosed in a tough cocoon, with particles of earth woven in with the silk.	No cocoon formed.
Adult	Abdomen without spines	Abdominal segments bearing double transverse rows of reddish spines.

FOOD PLANTS.

Both species of cankerworm seem to have a preference for apple and elm, but also feed on a wide range of food plants, including many of the common deciduous fruit and forest trees, particularly those included among the Rosaceae. The following list has been brought together from a number of sources; there has been no opportunity for verification of many of the records, but they are probably accurate for the most part.

Both species have been recorded as feeding on the following hosts:

Acer spp	Maple.
Acer negundo L	Boxelder.
Acer saccharinum L	Silver maple.
Betula spp	Birch.
Carya spp	Hickory.
Castanea dentata (Marsh.) Borkh	American chestnut.
Celtis occidentalis L	Hackberry.
Crataegus spp	Haw.
Cydonia oblonga Mill	Quince.
Fraxinus sp	Ash.
Juglans nigra L	Black walnut.
Prunus armeniaca L	Apricot.
Amygdalus persica L	Peach.
Prunus domestica galatensis Hort	Prune.
Pyrus communis L	Pear.
Malus sylvestris Mill	Apple.
Quercus spp	Oak.
Salix spp	Willow.
Tilia americana L	American linden.
Ulmus americana L	American elm.

In addition to the host plants already noted, the spring cankerworm has been recorded as feeding on the following hosts:

Betula alba L.	European white birch.
Hicoria glabra (Mill.) Britton	Pignut.
Hicoria ovata (Mill.) Britton	Shagbark hickory.
Catalpa speciosa Warder	Western catalpa.
Fraxinus americana L.	White ash.
Fraximus nigra Marsh.	Black ash.
Gleditsia triacanthos L.	Honey locust.
Ligustrum vulgare L.	Privet.
Prunus cerasus L.	Sour cherry.
Prunus pensylvanica L. f.	Pin cherry.
Prunus domestica L.	Plum.
Pyrus ioensis (Wood) Britton	Prairie crab.
Quercus macrocarpa Michx.	Mossycup oak.
Quercus muhlenbergii Engelm.	Chinquapin oak.
Quercus palustris DuRoi	Pin oak.
Quercus borealis maxima (Marsh.) Ashe	Red oak.
Rosa setigera Michx.	Prairie rose.
Rosa spp.	Roses, cultivated varieties.

In addition to the host plants listed as common to both species, the following have been recorded for the fall cankerworm:

Juglans cinerea L.	Butternut.
Prunus avium L.	Mazzard.
Prunus serotina Ehrh.	Black cherry.

DISTRIBUTION.

It has been difficult to determine from the literature the exact limits of the distribution of the respective cankerworms, since many accounts are indefinite as to the identity of the species under consideration. The approximate distribution of the two species is shown in the maps (figs. 1, 2) and is as follows:

FALL CANKERWORM.

The fall cankerworm occurs in the northeastern United States from North Carolina, Kentucky, and Missouri northward into southern Canada as far west as Manitoba, and along the northern border of the United States through the States of Minnesota, North Dakota, and Montana. It has also been reported from Colorado and California.

SPRING CANKERWORM.

The spring species is found throughout the northeastern and north-central part of the United States. It has been reported in the extreme southern part of Canada from Nova Scotia to Lake Huron, and also in Manitoba. The western limit of the main area of infestation seems to be Manitoba, Minnesota, Nebraska, Colorado, and Oklahoma. It has been recorded as far south as Jacksonville, Tex.; Arkansas, Tennessee, and North Carolina. It has also been found in California.

MEANS OF DISSEMINATION.

Owing to the wingless condition of the female moths, the natural spread of the cankerworms is very slow. This accounts for the occurrence of isolated infestations and their slowness in extending over additional territory. The cankerworms are carried to new localities largely by three methods. (1) The tiny recently hatched larvæ often spin down on threads and are blown about by the wind. The

greatest distance to which they may be blown in this manner does not seem to have been demonstrated, but they are doubtless blown at least from tree to tree. (2) The larger larvæ also suspend themselves by threads and some of them are often caught on passing vehicles and transported to new localities. (3) The egg masses, particularly of the fall species, which winters in this condition, are frequently car-

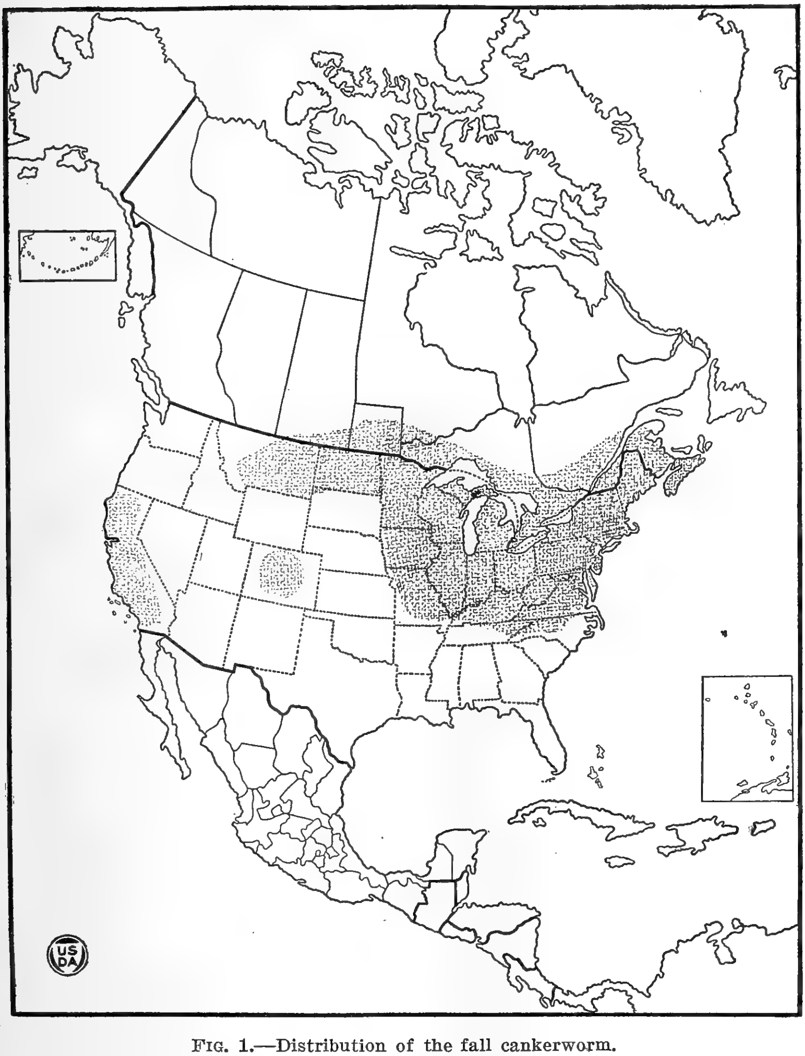


FIG. 1.—Distribution of the fall cankerworm.

ried to uninfested territory on nursery stock. In 1911 egg masses of the fall cankerworm were found in British Columbia on nursery stock imported from the United States (*34*). The clusters of eggs are easily overlooked, and doubtless many of them have been transported to other localities where the cankerworm had been hitherto unknown.

ECONOMIC IMPORTANCE.

During periods of abundance enormous damage is done by one or the other species of cankerworm, or by both working together. When especially abundant, the larvæ defoliate the trees, leaving only the midribs and larger veins of the leaves with a few ragged shreds of

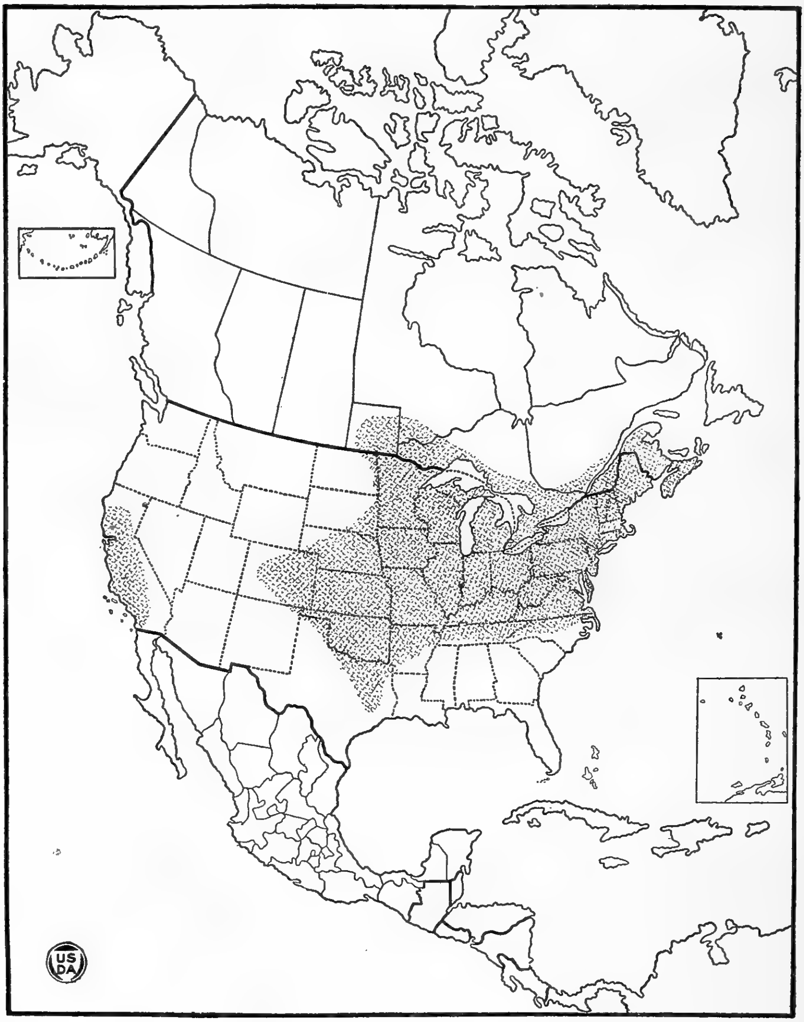
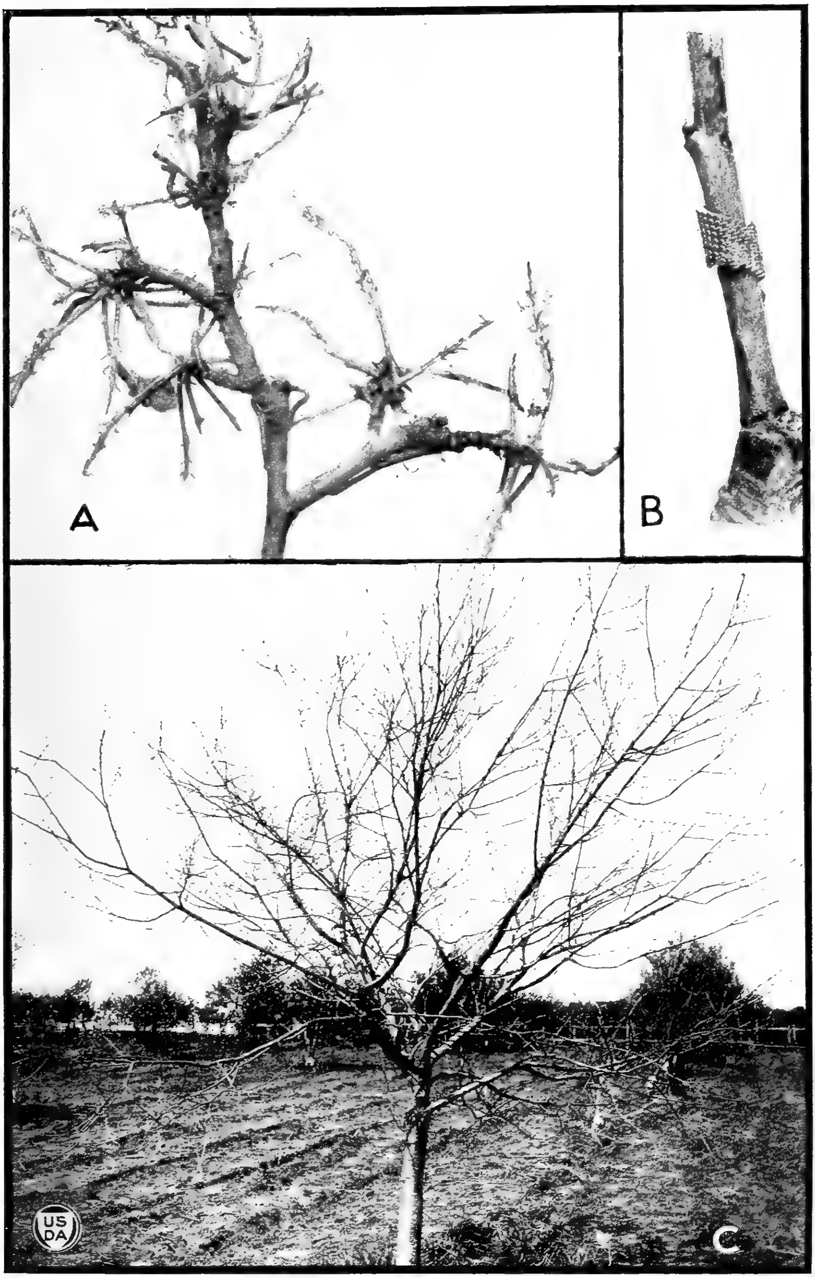


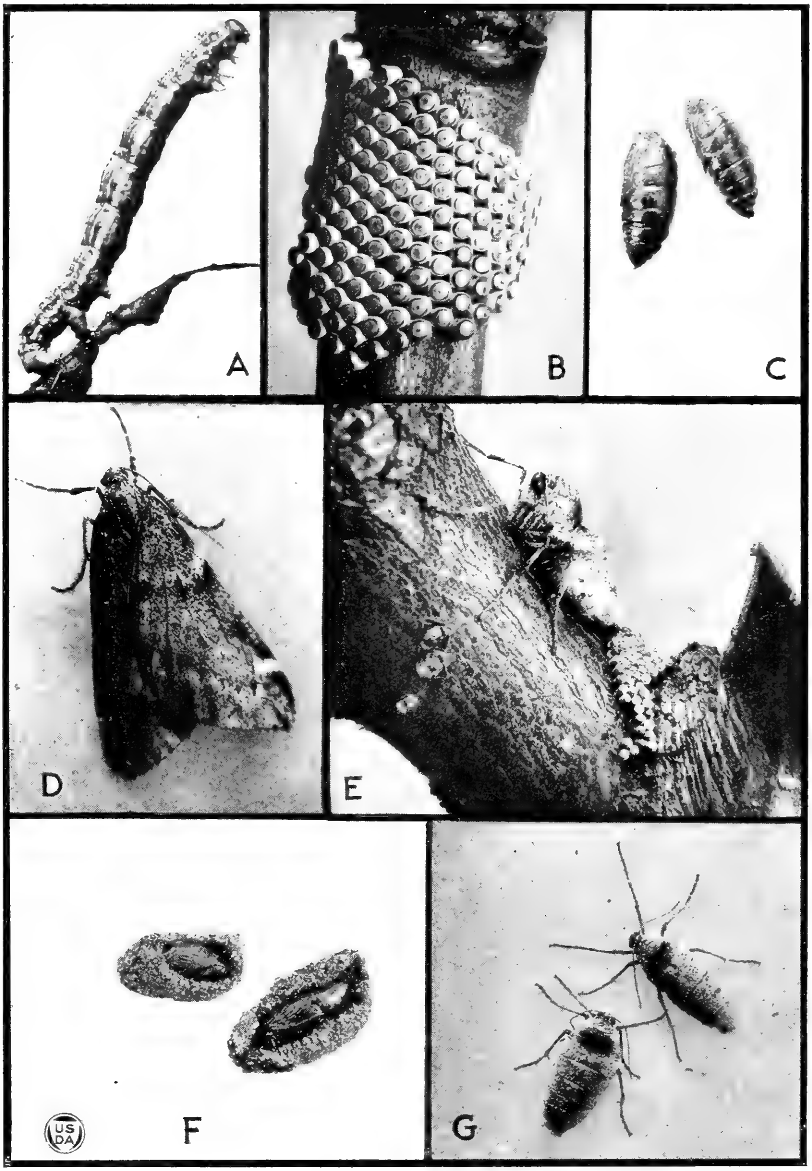
FIG. 2.—Distribution of the spring cankerworm.

leaf tissue. (Pl. I, A, C.) When the worms are somewhat less abundant, the leaves may not be entirely consumed, but many of them turn brown and dry. In either case, the trees are badly weakened, and, if defoliated for several years in succession, are likely to be killed. Young orchards not in bearing, which are often not thoughly sprayed, neglected orchards, and unprotected shade trees



CANKERWORMS

A, Apple twig defoliated by cankerworms; B, egg mass of fall cankerworm; C, young apple tree defoliated by cankerworms



FALL CANKERWORM

A, Full-grown larva (× 2½); B, egg mass (× 7); C, pupæ (× 2¼); D, male moth (× 3); E, female moth laying eggs (× 3); F, pupæ in cocoons (× 1¾); G, female moths (× 2¼)

suffer the most severe losses. In orchards which are well cared for and consistently sprayed with arsenicals, there is little opportunity for the cankerworms to gain a foothold. Such orchards are usually comparatively immune from attack, even during a period when cankerworms are abundant in the immediate neighborhood. As far as orchards are concerned, the cankerworm may therefore be rated as a pest which may be easily controlled, but which during periods of abundance may do serious damage if the orchards are neglected. As a shade-tree pest, the cankerworm is periodically of great importance.

FALL CANKERWORM.

DESCRIPTIONS.

EGG MASS.

Counts were made at Wallingford, Conn., of the number of eggs in 35 egg masses collected in the field in 1919 and 1920 and 76 egg masses laid in captivity in the fall of 1919. In the field-collected eggs the maximum number in a mass was 244, the minimum 3, and the average 129.3; in those laid in captivity the maximum was 408, the minimum 4, and the average 101.2. Thus the number of eggs in a single egg mass is seen to vary from a very few to several hundred, although the largest masses probably resulted from the efforts of more than one moth. The largest cluster noted, that of 408 eggs, is known to have been contributed to by two females.

Britton (*33*) reports for 100 egg masses collected in the field an average of 94 eggs, and for 65 laid in captivity an average of 148.

The eggs are laid in various places, but usually on the smaller branches and twigs, frequently very near the tips. The moths have been known to deposit their eggs on fence posts and the sides of houses. The masses are often found on tree trunks, especially if a barrier has interrupted the progress of the moth. On a tree trunk or other nearly flat surface, they form a flat mass; on a very small twig the cluster is cylindrical, frequently encircling the twig completely (Pl. I, B; II, B). The eggs are laid in straight rows following the length of the twig, each egg opposite the space between two eggs in the adjacent row, and are placed so closely together that their natural circular outline frequently becomes slightly hexagonal where they come in contact at the top.

The individual egg is somewhat cylindrical, rounded at the base, and smaller at the base than at the top, which is slightly convex with a small pit at the center. Measurements of a number of eggs from several different masses averaged as follows: Height 0.70 millimeter, width at top 0.50 millimeter, width at base 0.42 millimeter. In general color the egg is an ashy gray which is lightest at the base and on the sides. The greater part of the top, or cap, of the egg is a darker gray to brown, having near the outer edge a depressed circle within which is a narrow circle of brown. The surface of the cap of the egg is very minutely and irregularly sculptured, with a few of these fine lines radiating in an irregular fashion from the central depression.

LARVA.

First stage.—Width of head 0.36 to 0.39 millimeter, average 0.37 millimeter; length when newly hatched 1.84 millimeters, when full-fed about 4.5 millimeters. General color of newly hatched larva yellowish green to olive green. Head

much wider than the rest of the body, yellowish green to yellowish brown with a narrow posterior margin of brown. Thoracic shield varying from much the same color as the head to olive green, lighter anteriorly. Thorax and abdomen yellowish green to olive green, dorsum with a median longitudinal darker stripe. Between the dorsal and lateral rows of tubercles is a much narrower longitudinal dark line. Tubercles pale, with a dark green spot in the center of each. Anal segment light green.

Ventral surface lighter green than dorsal. Legs about concolorous with the ventral surface, dusky at the tips. Three pairs of prolegs: A very small pair on the fifth abdominal segment, and larger ones on the sixth and anal segments. Hairs very short and sparse.

When full fed, the larvæ become a lighter green with narrow longitudinal pale lines, which become more distinct in the next instar.

Second stage.—Width of head 0.61 to 0.66 millimeter, average 0.64 millimeter, length when full fed about 8 millimeters. General color green, varying from pale yellowish green to very dark green. Individuals from the same egg cluster often show wide variations in color. Head light green with varying areas of dusky green; in very dark specimens the head becomes almost entirely dark green. The middle of the dorsal surface of the body has a darker longitudinal stripe, which usually does not extend far into the anal segment. On each side of this median stripe is a pair of light, narrow, longitudinal lines; and below the spiracles, following the folds of the integument, an irregular light line. Tubercles concolorous with the surrounding surface, except for a dark dot in the center. Spiracles dark-margined. Ventral surface varying from light to dark green with a lighter median area.

Third stage.—Width of head 1.05 to 1.13 millimeters, average 1.09 millimeters; length when full fed 14 to 15 millimeters. General color green, varying from pale to very dark, almost black. Larvæ reared in battery jars in the insectary averaged much darker in color than those in the same stage collected in the field. Head varying from pale green to very dark, almost black; sometimes a mottled mixture of light and dark green. Markings similar to those described in the previous instar. On each side of the median dorsal stripe is a pair of light longitudinal lines, and in the dorsal area there is frequently a faint suggestion of a third pair of lines. Below the spiracles a broader irregular light line follows the folds of the integument. In some individuals, especially the lighter colored ones, the pale longitudinal lines become more or less partial, being broken and interrupted. Anal segment sometimes mottled with a very dark green. Spiracles dark-margined. Ventral surface lighter in color than the dorsal, usually with the median longitudinal portion lighter still.

Fourth stage (Pl. II, A).—Width of head 1.65 to 1.93 millimeters, average 1.77 millimeters; length when full fed and ready to enter the ground 20 to 27 millimeters. General color, as in previous instars, very variable, ranging from very light green to very dark and sometimes brownish green. Head and anal segment varying from a very pale to darker green, sometimes mottled with black, sometimes almost entirely black. In light-colored individuals the head is frequently mottled with areas of creamy white. Body markings as described in previous instar, with further variations. The dorsal area frequently has in it faint suggestions of additional light longitudinal lines. Some of the lighter colored larvæ have a series of irregular splotches of black behind each spiracle, that on the prothorax extending in front of the spiracle; in other larvæ some of these dark spots are present and others missing. Some light-colored individuals have darker markings dorsally on the prothorax and on the seventh and eighth abdominal segments. The light longitudinal lines frequently have a yellowish tinge, and in rare cases a reddish brown color. Other variations doubtless occur. Spiracles margined with dark brown. Ventral surface pale green, even in darker specimens, lighter in color along the median line, and sometimes with a pair of faint, interrupted, light, longitudinal lines on the outer edge.

COCOON.

Broadly oval in shape, 10 to 13 millimeters in length, with particles of grit and soil woven in with the silk. The cocoon is very tough, so much so that it is difficult to open without injury to the larva or pupa within (Pl. II, F).

Previous to pupation, the larva lies doubled within the cocoon.

PUPA.

Stout, 7 to 10 millimeters long. General color greenish brown, wing pads more greenish, margins of the segments a deeper brown. Surface without spines, somewhat finely punctate. Anal segment with a stout curved spine, terminating in a pair of curved bristles (Pl. II, C, F).

MOTH.

The following description has been condensed from Riley (*24*):

Male (Pl. II, D).—Expanse of wings 26 to 34 mm. Palpi rudimentary with joints indistinguishable. Antennae with over 50 joints, the longest not twice as long as wide, each with one pair of fascicles of slightly curled hairs. Abdomen without spines. Wings less transparent, more glossy than those of *P. vernata*, not striate, the scales on the average longer and more firmly attached. Upper surface of front wings brownish gray, but somewhat darker, with a purplish reflection, crossed with two jagged, whitish bands, the outermost suddenly bending inward near costa, where it forms a pale, quadrate spot, relieved by a darker shading of the wing around it; the bands sometimes so obsolete as to leave only this pale spot; but more often relieved on the sides towards each other by a dark shade, most persistent on the veins. Hind wings grayish brown, with a faint blackish discal dot. In most specimens a curved white band runs across the wing, and the veins inside this band and on the hind border are generally dotted. Under surface with a dusky discal spot on each wing, and with the outer pale band on upper surface of front wings as well as that of the hind wings showing distinctly, the former relieved by a dusky spot inside at costa.

Female (Pl. II, E, G).—Length 6 to 10 mm. Antennae with over 50 joints, the longest hardly longer than broad; uniform in diameter, without pubescence. Body and legs smooth, clothed with glistening brown and white truncate scales intermixed, giving it an appearance of uniform, shiny, dark ash gray, somewhat paler beneath. Abdomen tapering rather bluntly behind, without spines.

SEASONAL HISTORY AND HABITS.

The following observations, recorded largely in the insectary, were carefully compared with field conditions, and were found to agree very closely.

EMBRYONIC DEVELOPMENT.

The development of the larva within the egg is apparently not completed until a few days previous to hatching. When fully developed, the larva lies doubled, with head and anal extremity near together just beneath the cap of the egg.

HATCHING OF THE EGGS.

In the vicinity of Wallingford, Conn., in a normal season, the eggs hatch early in May, beginning as the apple blossoms of midseason varieties are showing pink, and ending before they have opened. In 1918 hatching began May 4; in 1919 on May 1; in 1920, which was a very cold and late season, on May 11, and in 1921, an abnormally early season, on April 16. The relation between the stage of development of the apple buds and the hatching of the cankerworms was approximately the same each year. Hatching in a given locality may extend over a period of 12 days, depending on weather conditions, but ordinarily the greater part of it occurs within 4 or 5 days. With individual egg clusters, most of the hatching is completed within 2 or 3 days after the first egg hatches.

Table 2 gives a summary of the hatching records of 31 egg masses collected in the field in 1919 and 6 egg masses collected in 1920.

TABLE 2.—*Hatching of eggs of the fall cankerworm from egg masses collected in the field, Wallingford, Conn., 1919 and 1920.*

FROM 31 EGG MASSES, 1919.

Date.	Number of eggs hatched	Temperature.			Date.	Number of eggs hatched	Temperature.		
		Maximum.	Minimum.	Average.[1]			Maximum.	Minimum.	Average.[1]
		° F.	° F.	° F.			° F.	° F.	° F.
May 1	226	54	38	46.5	May 7	378	54	45	50.1
May 2	152	70	45	57.4	May 8	48	78	52	62.0
May 3	200	73	48	58.1	May 9	2	52	47	50.5
May 4	833	77	47	61.4	May 10	2	47	40	42.6
May 5	1,003	89	52	65.2	May 11	1	48	41	44.0
May 6	599	66	43	53.0	May 12	1	50	42	46.0

FROM 6 EGG MASSES, 1920.

Date.	Number of eggs hatched	Maximum.	Minimum.	Average.[1]	Date.	Number of eggs hatched	Maximum.	Minimum.	Average.[1]
May 11	150	66	49	54.7	May 15	28	64	46	54.8
May 12	190	66	44	56.0	May 16	12	71	43	58.1
May 13	168	57	47	50.5	May 17	20	74	47	60.6
May 14	88	54	45	48.7					

[1] This column represents the average of hourly temperatures recorded by the thermograph.

In hatching, the larva gnaws a hole in the cap of the egg, usually including most of the area within the dark circle. Sometimes the hole is eaten out nearly round, but more often a small segment of the circle is left at one side. The opening through which the larva will emerge is about two-thirds the width of the head, so that in leaving the egg, the larva usually tips its head and works it through sideways.

In many cases, for some unknown reason, quite a proportion of the eggs failed to hatch. In 1920 five egg clusters, collected in the field a short time before hatching, gave only about 53 per cent of the possible number of larvæ. None of these egg masses were parasitized.

HABITS OF THE LARVÆ.

The newly hatched larvæ make their way to the unfolding leaves and buds and commence feeding. At first they gnaw small pits in either surface of the leaves, but they soon eat all the way through, making small perforations here and there. The younger larvæ seem to have a preference for the young, tender, newly formed leaves, and do most of their feeding near the tips of the rapidly growing shoots. When the larvæ are numerous, the leaves may be skeletonized, little being left except the veins and shreds of leaf tissue.

After the first instar, larger and larger irregular holes are made in the leaves, and when the larvæ are nearly full grown, they may consume almost entire leaves, leaving only the midribs and larger veins with a few ragged shreds of leaf tissue. Unless the larvæ are numerous, however, the feeding is not likely to be very conspicuous, as they have a strong tendency to wander, consuming a little here and there as they go. The worms also feed occasionally in the blossoms.

When disturbed, many of the larvæ drop suspended on threads. Those remaining on the leaves are often hard to find, because of their similarity in color to the leaves.

NUMBER OF LARVAL STAGES.

Some writers have reported five larval stages for the fall cankerworm, but all larvæ under observation at Wallingford have invariably entered the ground at the close of the fourth instar.

LENGTH OF FEEDING PERIOD.

Table 3 gives the larval feeding period for 165 larvæ from 6 egg masses in 1919 and for 106 larvæ from 5 egg masses in 1920. These data are summarized in Table 4, in which it will be noted that a larva may complete its development in as short a time as four weeks, or it may require nearly six. Practically all of them, however, completed their feeding in from 30 to 35 days, and in both seasons the average was slightly over 32 days.

TABLE 3.—*Length of larval feeding period of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

FOR 165 LARVÆ FROM 6 EGG MASSES, 1919.

Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.	Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.
May 1	June 1	1	31	May 4	June 7	3	34
Do	June 2	2	32	Do	June 8	1	35
Do	June 3	6	33	Do	June 10	2	37
Do	June 4	1	34	Do	June 11	1	38
Do	June 7	1	37	May 5	June 4	6	30
May 2	June 3	7	32	Do	June 5	8	31
Do	June 4	7	33	Do	June 6	26	32
Do	June 5	2	34	Do	June 7	2	33
May 3	June 4	4	32	May 6	June 5	7	30
Do	June 6	1	34	Do	June 6	16	31
Do	June 7	3	35	Do	June 7	5	32
May 4	June 1	1	28	Do	June 9	2	34
Do	June 3	1	30	Do	June 10	1	35
Do	June 4	8	31	May 7	June 6	2	30
Do	June 5	21	32	Do	June 10	1	34
Do	June 6	16	33				

FOR 106 LARVÆ FROM 5 EGG MASSES, 1920.

Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.	Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.
May 11	June 10	2	30	May 13	June 16	1	34
Do	June 11	13	31	Do	June 17	1	35
Do	June 12	4	32	Do	June 19	1	37
Do	June 14	2	34	Do	June 20	1	38
Do	June 15	3	35	Do	June 23	1	41
May 12	June 12	1	31	May 14	June 14	5	31
Do	June 13	4	32	Do	June 15	3	32
Do	June 14	6	33	May 15	June 15	3	31
Do	June 15	7	34	Do	June 16	1	32
Do	June 16	1	35	May 16	June 16	2	31
Do	June 20	1	39	Do	June 18	1	33
May 13	June 12	14	30	Do	June 23	2	38
Do	June 13	10	31	May 17	June 16	1	30
Do	June 14	6	32	Do	June 19	1	33
Do	June 15	7	33	Do	June 22	1	36

TABLE 4.—*Length of larval feeding period of fall cankerworm, Wallingford, Conn., 1919 and 1920. Summary of Table 3.*

Number of days.	Number of larvæ.	
	In 1919.	In 1920.
28	1	0
29	0	0
30	16	17
31	33	34
32	65	18
33	31	15
34	10	10
35	5	5
36	0	1
37	3	1
38	1	3
39	0	1
40	0	0
41	0	1
Total	165	106
Average length of feeding period in days	32.1	32.2

Table 5 records observations on the average length of the different larval stages of the fall cankerworm at Wallingford during 1919 and 1920.

TABLE 5.—*Average length of larval stages of fall cankerworm, Wallingford, Conn., 1919 and 1920.*

Stage.	1919		1920	
	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.
First	255	13.27	127	11.18
Second	213	5.85	115	5.38
Third	195	5.13	112	5.21
Fourth (to end of feeding)	165	7.94	106	10.51
Total		32.2		32.3

It will be noted that the total larval feeding period in Table 5 differs slightly from that given in Table 4, which is based only on those larvæ completing their development, while the data in Table 5 are based on different numbers of larvæ in the successive stages.

ENTERING THE GROUND.

For cocooning and pupation the larvæ enter the ground to a depth of several inches. In battery jars containing about 6 inches of loose soil, they go down about 2½ inches. In the field the depth varies according to soil conditions.

To all external appearances the cocoon is complete about 24 hours after the larva has entered the soil, although in some cases its construction may take 48 hours.

Table 6 shows the dates the larvæ entered the soil in 1919 and 1920. On June 25, 1920, two days after the last larva under observation in the insectary at Wallingford had entered the ground, several larvæ were noted at Milford, Conn., about 24 miles southwest of Walling-

ford, which were still feeding, but were apparently full grown and about on the point of leaving the tree. With this one exception, the data in the table agree with observations made in the field.

TABLE 6.—*Entrance into ground of larvæ of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

In 1919.				In 1920.			
Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.
June 1	2	June 8	1	June 10	2	June 18	1
June 2	2	June 9	2	June 11	13	June 19	2
June 3	14	June 10	4	June 12	19	June 20	2
June 4	26	June 11	1	June 13	14	June 21	0
June 5	38			June 14	19	June 22	1
June 6	61	Total	165	June 15	23	June 23	3
June 7	14			June 16	6		
				June 17	1	Total	106

PREPUPAL PERIOD.

It is impossible to determine by daily examination the exact length of the prepupal period, due to the toughness of the cocoon, which makes it difficult to avoid injuring the larva while opening the cocoon for examination. The approximate period, however, was ascertained as follows: A number of larvæ were allowed to enter soil in battery jars and construct their cocoons, which were then sifted out and placed in soil in flowerpots sunk in the ground in the insectary yard. At intervals a number of cocoons were dug up, examined, and the number of larvæ and pupæ recorded. After having been disturbed, and very possibly injured, these individuals were not used for further records, but a fresh lot was used each time. The results of these examinations were as follows: Up to and including the twenty-sixth day none had pupated; on the twenty-seventh day a few pupæ were found; on the thirtieth day half or more of them had transformed, and on the thirty-fourth and thirty-fifth days four-fifths of them had pupated. Taking into consideration the possibility that due to disease, parasites, or injury, a certain proportion of the larvæ might never have pupated, it seems likely that practically all pupation takes place in 27 to 35 days, with the average prepupal period falling between 31 and 32 days for the normal season.

EMERGENCE OF MOTHS.

The moths may begin to emerge at any time in the fall, but do not usually leave the ground in numbers until freezing weather has occurred. In 1919 the lowest temperature previous to the first emergence was 32° F.; in 1920 the lowest was 37° F. In 1919 the lowest temperature preceding emergence in numbers was 26° F., on November 10, but a much greater emergence followed a minimum temperature of 20° F., on the 16th. In 1920 the first period of emergence in numbers began on November 18, after temperatures of 19° F. on the 13th and 21° F. on the 14th. The maximum emergence followed after a minimum temperature of 24° F. on the night of November 29.

Table 7 gives data relative to the emergence of moths in 1919 and 1920. These data include records from two sources. In a few of the cages nearly full-grown larvæ collected in the field were allowed to complete their feeding and enter the soil normally; the material in the other soil cages was transferred after having entered soil and spun cocoons in battery-jar cages in the insectary. Emergence occurred over approximately the same periods for both classes of material, the peaks of the emergence coinciding exactly, and as a matter of convenience the records are here combined in one table.

With the material collected in the field and allowed to enter the soil normally, it is not known exactly how many completed their feeding, entered the soil, cocooned, and pupated.

Out of 157 cocoons placed in the soil cages in 1919, 90 moths, or 57 per cent of the possible total, emerged. The following year 247 moths emerged from 312 cocoons, or 79 per cent of the possible total.

TABLE 7.—*Emergence of moths of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

IN 1919.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Minimum.	Maximum.	Average.	
			°F.	°F.	°F.	
Nov. 2	....	1	35	62	47.5	Rain.
Nov. 3	....	3	29	51	39.1	Clear.
Nov. 4	....	4	36	51	43.8	Cloudy.
Nov. 5	....	3	37	46	40.8	Rain.
Nov. 6	....	0	37	45	39.4	Clear.
Nov. 7	....	0	34	45	39.2	Do.
Nov. 8	....	0	31	51	38.4	Do.
Nov. 9	....	1	27	55	36.8	Do.
Nov. 10	....	0	26	59	37.8	Do.
Nov. 11	....	19	32	50	43.4	Light rain.
Nov. 12	....	3	48	57	52.4	Rain.
Nov. 13	....	0	31	55	43.3	Do.
Nov. 14	....	1	27	47	33.7	Clear.
Nov. 15	....	0	24	44	32.5	Do.
Nov. 16	1	9	20	49	34.7	Do.
Nov. 17	1	69	35	54	43.2	Do.
Nov. 18	....	21	33	58	44.0	Do.
Nov. 19	....	0	25	40	33.9	Do.
Nov. 20	....	0	20	32	24.9	Do.
Nov. 21	....	0	20	51	35.2	Do.
Nov. 22	....	13	39	51	44.5	Do.
Nov. 23	....	2	33	51	40.6	Do.
Nov. 24	....	1	30	49	36.8	Do.
Nov. 25	....	0	28	49	40.5	Do.
Nov. 26	....	0	37	48	44.2	Rain.
Nov. 27	....	0	31	42	37.2	Do.
Nov. 28	....	0	28	33	30.3	Cloudy.
Nov. 29	....	1	32	58	42.4	Rain.
Nov. 30	....	0	31	59	49.2	Clear.
Dec. 1	....	0	25	40	30.5	Do.
Dec. 2	....	0	22	40	31.2	Do.
Dec. 3	....	0	11	26	17.9	Do.
Dec. 4	....	0	9	33	18.5	Do.
Dec. 5	....	0	15	32	24.0	Do.
Dec. 6	....	0	21	39	30.1	Rain.
Dec. 7	....	0	40	44	41.6	Do.
Dec. 8	....	0	32	40	36.2	Do.
Dec. 9	....	1	35	45	37.4	Do.

TABLE 7.—*Emergence of moths of the fall cankerworm, Wallingford, Conn., 1919 and 1920*—Continued.

IN 1920.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Minimum.	Maximum.	Average.	
			°*F.*	°*F.*	°*F.*	
Oct. 28	....	1	52	67	60.2	Rain.
Oct. 29	....	0	39	53	46.5	Cloudy.
Oct. 30	....	0	36	49	42.0	Partly cloudy.
Oct. 31	....	2	39	65	52.3	Clear.
Nov. 1	....	0	43	64	52.8	Partly cloudy.
Nov. 2	....	0	40	63	52.0	Rain.
Nov. 3	....	0	43	62	51.1	Clear.
Nov. 4	....	1	35	57	46.7	Do.
Nov. 5	....	1	42	62	49.9	Do.
Nov. 6	....	1	40	56	46.0	Do.
Nov. 7	....	5	38	49	43.5	Rain.
Nov. 8	....	0	37	56	44.0	Do.
Nov. 9	....	1	35	59	50.3	Cloudy.
Nov. 10	....	2	33	58	47.2	Partly cloudy.
Nov. 11	....	0	29	43	34.8	Clear.
Nov. 12	....	0	25	44	33.1	Do.
Nov. 13	....	0	19	45	30.1	Do.
Nov. 14	....	0	22	45	32.1	Do.
Nov. 15	....	4	27	37	32.5	Light snow.
Nov. 16	....	0	34	38	35.8	Rain.
Nov. 17	....	1	36	46	39.5	Do.
Nov. 18	....	43	35	57	42.3	Clear.
Nov. 19	....	18	32	51	41.3	Do.
Nov. 20	....	15	37	51	42.8	Do.
Nov. 21	....	0	29	35	30.8	Light rain.
Nov. 22	....	5	32	41	36.0	Rain.
Nov. 23	....	14	37	48	41.8	Do.
Nov. 24	....	1	33	41	36.8	Rain and snow.
Nov. 25	....	0	31	33	32.7	Snow.
Nov. 26	....	1	28	42	32.2	Clear.
Nov. 27	....	10	30	39	34.9	Rain.
Nov. 28	....	9	31	36	34.9	Do.
Nov. 29	....	0	24	50	30.6	Clear.
Nov. 30	....	63	25	44	36.9	Cloudy.
Dec. 1	....	35	33	41	35.7	Rain.
Dec. 2	1	7	33	51	40.0	Partly cloudy.
Dec. 3	....	13	26	41	34.8	Clear.
Dec. 4	....	115	38	54	43.8	Rain.
Dec. 5	....	15	41	55	46.2	Do.
Dec. 6	....	1	34	42	39.3	Light rain.
Dec. 7	....	0	29	42	34.6	Partly cloudy.
Dec. 8	....	0	24	48	29.4	Clear.
Dec. 9	....	0	25	35	30.5	Partly cloudy.
Dec. 10	....	1	32	36	34.0	Do.

Upon emerging, the females make their way to the base of a near-by tree, and commence their ascent. If the weather is unfavorable—cold or rainy—the ascent may occupy several days. During especially cold periods, moths have been observed motionless in one spot on the trunk of a tree for 48 hours. Under ordinary conditions, however, their progress is much more rapid. The moths do not always reach a tree in their efforts to find a suitable place for oviposition, in such cases laying their eggs wherever they are able.

PROPORTION OF THE SEXES.

For some unexplained reason, all larvæ which were carried through in the insectary from egg to adult developed into female moths, and from field material, collected for the most part when the larvæ were in the last stage, only two males emerged in 1919 and

one male in 1920. In 1920 females were to be found in the field for 10 days before any males could be found. C. V. Riley, in his Seventh Report on the Insects of Missouri (*17*), noted that the females outnumbered the males, and the following year (*20*) stated that out of 58 reared specimens 56 were females. Other writers have mentioned this seeming preponderance of females, which is at present unexplained.

ACTIVITY OF THE MOTHS.

The greatest activity of the moths occurs just at dusk, although they continue to be more or less active during the night, and occasionally to a very limited extent during the daytime, especially if the day is dark and cloudy. During the day the moths are for the most part quiescent, the females often passing the time in the more or less protected places on the trunks of the trees. The winged male moths may pass the day in similar locations, and are also likely to be found in the grass and débris at the base of the tree.

With darkness a period of great activity begins if the weather is mild, and during this period mating usually takes place, although mated pairs are to be found throughout the night, and occasionally during the day. Moths *in coitu* have been observed at different times, but the male moths usually seem to pay comparatively little attention to females which have been fertilized and have been laying eggs.

PREOVIPOSITION PERIOD.

The length of time elapsing between the emergence of the female moth and the deposition of her eggs varies greatly, depending chiefly on weather conditions and upon whether the female has mated. During very cold weather the upward progress of the moth is very slow, and a number of days may elapse before egg-laying commences. Unfertilized females will lay only a very few scattered eggs. In 1920 a total of 20 females which emerged between October 28 and November 7 were placed in a wire cage in the insectary yard. November 10 one male was added, but apparently escaped or died, as it could not be found the following day. The day this male was placed in the cage a few scattered eggs were laid, but no more were found for more than a week. On the 18th six males were collected in the field and placed in the cage, and on the following day eight egg clusters were deposited. In this case the minimum preoviposition period was at least 12 days, oviposition evidently having been delayed pending the arrival of the males. On the other hand, a preoviposition period of slightly more than 24 hours has been noted in a number of instances, and under favorable conditions this period is usually less than three days.

Table 8 gives data in connection with the oviposition of 17 females isolated in battery jars in the insectary. Males were collected in the field, as none were available from the soil cages. It is not known why two of the moths (Nos. 3 and 17) delayed so long before laying their eggs. The average preoviposition period as calculated for these particular individuals has little significance, the length of this period being so very dependent on weather conditions, which are extremely variable in the late fall and early winter.

TABLE 8.—*Oviposition of individual moths of the fall cankerworm, Wallingford, Conn., 1920.*

Moth No.	Date female emerged.	Date male added.	Mated.	First eggs.	Last eggs.	Total masses.	Total eggs.	Preoviposition period.
								Days.
1	Nov. 18	Nov. 18	Nov. 19	Nov. 19	Nov. 20	2	169	1
2	...do...	...do...	...do...	...do...	Nov. 19	2	209	1
3	...do...	...do...	Nov. 20	Dec. 3	Dec. 4	2	310	15
4	...do...	...do...	Nov. 19	Nov. 19	Nov. 23	3	355	1
5	...do...	...do...	....	Nov. 20	Nov. 22	2	257	2
6	...do...	...do...	Nov. 19	Nov. 19	Nov. 19	2	261	1
7	...do...	...do...	...do...	...do...	...do...	1	237	1
8	...do...	Nov. 19	...do...	...do...	...do...	1	227	1
9	...do...	...do...	....	Nov. 20	Nov. 22	2	251	2
10	...do...	...do...	....	Nov. 19	Nov. 19	3	279	1
11	...do...	...do...	Nov. 19	...do...	Nov. 23	3	384	1
12	...do...	...do...	...do...	...do...	Nov. 28	7	277	1
13	...do...	...do...	...do...	...do...	Nov. 23	2	317	1
14	...do...	...do...	...do...	Nov. 20	Nov. 22	2	280	2
15	...do...	...do...	...do...	Nov. 19	Nov. 19	1	228	1
16	Nov. 19	...do...	Nov. 20	Nov. 20	Nov. 28	6	284	1
17	...do...	...do...	....	Dec. 15	Dec. 15	1	10	26
Total						42	4,335	....
Average per individual						2.5	255	3.5

WEATHER RECORDS.

Date.	Temperature.			Remarks.
	Minimum.	Maximum.	Average.	
	°*F.*	°*F.*	°*F.*	
Nov. 18	35	57	42.3	Clear.
Nov. 19	32	51	41.3	Do.
Nov. 20	37	51	42.8	Do.
Nov. 21	29	35	30.8	Light rain.
Nov. 22	32	41	36.0	Rain.
Nov. 23	37	48	41.8	Do.

OVIPOSITION.

Whenever possible, the moths usually make their way out to the smaller twigs before laying their eggs, although they sometimes deposit them on the trunk and larger branches, and will lay almost anywhere if they are unable to reach the places usually preferred for oviposition. Instances are on record of the oviposition of eggs on fence posts and on the sides of buildings. In captivity the moths often lay their eggs on the tops and sides of the cages instead of on the twigs provided for them. If halted by a barrier, they frequently place their eggs on the trunk beneath it.

Egg laying usually proceeds at a fairly rapid rate. Six of the moths noted in Table 8 emerged, mated, and laid their entire supply of more than 200 eggs each, within 48 hours. All except one moth (No. 17) disposed of all the eggs in their abdomens; for some reason this particular moth laid only 10 eggs, dying with 183 remaining in her abdomen. The eggs may be laid in one large mass, or divided among a number of smaller clusters.

LONGEVITY OF THE MOTHS.

In the protection of the rearing jars, some of the female moths lived a long time. Of the 17 females noted in Table 8, all lived more

than two weeks; one lived 32 days, and the average length of life was 27 days. Practically all eggs were laid during the first few days of confinement, and after this the moths were very sluggish and inactive. Under field conditions, the moths doubtless perish in a shorter time.

Males of a known date of emergence were not available, but those captured in the field and confined with the moths noted in Table 8 lived almost as long as the females, although it would hardly seem likely that the fragile-winged males would survive long under field conditions.

SPRING EMERGENCE.

It has been frequently recorded that the emergence of a few of the moths is often delayed until early spring. On March 26, 1920, one or two days after the frost had left the ground, a female moth, evidently recently emerged, was found in an orchard near the Wallingford laboratory. None emerged from the soil cages.

SPRING CANKERWORM.

DESCRIPTIONS.

EGG.

The eggs (Pl. III, A) are laid in crevices in the bark of the tree in loose clusters varying in number from a very few to more than 100. Quaintance (*32*) reported the number as varying from 17 to 119, with an average for 12 masses of 47. Counts by the present writers of 27 egg clusters, some of them laid in captivity and others collected in the field, showed a maximum of 75 eggs to the cluster, a minimum of 14, and an average of 34.5.

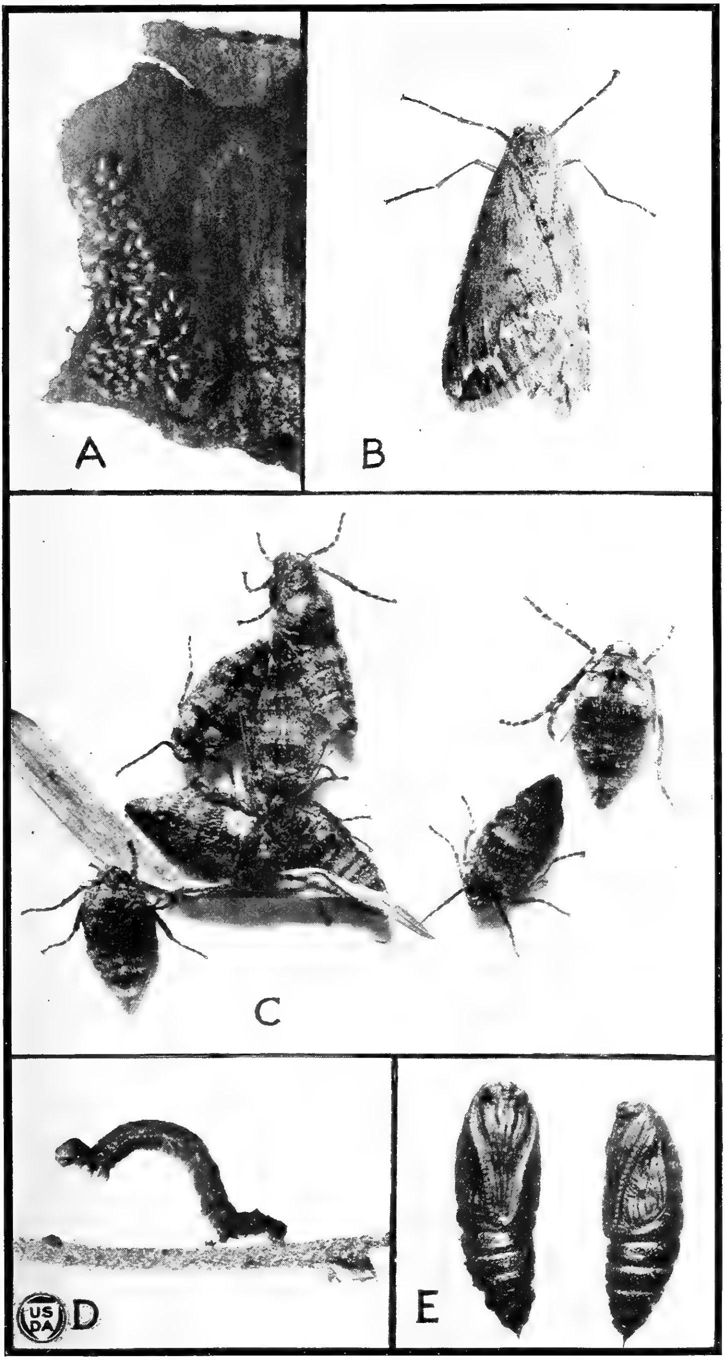
The egg cluster has no definite form, and the eggs may be either scattered or placed in a loose heap, somewhat stuck to each other and to the surface next to which they have been placed.

The individual egg is broadly oval in shape, one end being somewhat more broadly rounded than the other. The length varies from 0.66 to 0.85 millimeter, with an average of 0.77 millimeter; the width varies from 0.39 to 0.50 millimeter, averaging 0.45 millimeter. When first laid, the egg is a shining white, but in a few hours turns a light pearly yellowish brown with an iridescence giving purple and green reflections. The eggshell is thin with minutely sculptured longitudinal ridges.

LARVA.

First stage.—Width of head 0.25 to 0.28 millimeter, average 0.27 millimeter; length when newly hatched about 1.5 millimeters, when full-fed about 3.5 millimeters. General color dark olive green to black; head dull dark brown to black; dorsum with a central longitudinal interrupted dull white line, divided in the middle by a narrow, broken, olive-green line; each side with a lateral dull white line. Venter brownish olive-green; thoracic legs pale; prolegs, which are present on the sixth and anal segments, pale. Tubercles pale, tipped with darker color. Setæ short, pale yellow to white.

Second stage.—Width of head 0.41 to 0.50 millimeter, average 0.45 millimeter; length when full fed 5.5 to 6.5 millimeters. General color dark brownish olive-green, practically black in most cases; head dull black, whitish across clypeus, with additional light markings which vary from white to pale brown; dorsal surface with a median pair of narrow, broken, irregular white lines separated by a median olive-green line; along each side is a fairly broad, dull white line, more or less dotted with darker spots; between the lateral and dorsal lines just noted are sometimes faint suggestions of one or two narrow



SPRING CANKERWORM

A, Eggs on inner surface of a bit of bark (× 3½); B, male moth (× 2½); C, female moths (× 3½); D, partly grown larva (× 3); E, pupæ (× 4)

longitudinal lines, one of which nearly touches the broader lateral line; ventral surface not quite as dark as dorsal; thoracic legs concolorous with adjacent ventral surface; prolegs somewhat paler on inner side with darker areas on outer surface. Tubercles tipped with a dark spot; setæ short and dark: abdominal segment 8 somewhat enlarged dorsally.

Third stage.—Width of head 0.69 to 0.77 millimeter, average 0.73 millimeter; length when full fed 7.5 to 8 millimeters. General color variable, usually very dark olive-green to dull black with paler markings which vary in color from white to a dirty pale brown. Head brown to dull black with two irregular transverse pale mottled areas across lower portion of head, and additional mottlings of pale dirty brown to white; longitudinal lines of paler color much as described in previous instar; ventral surface slightly paler, with a pair of irregular, somewhat broken, paler median longitudinal lines on abdomen to prolegs; thoracic legs and prolegs about concolorous with adjacent surface; tubercles inconspicuous, tipped with a darker spot; setæ very minute. Eighth abdominal segment somewhat enlarged dorsally.

Fourth stage.—(Pl. III, D). Width of head 1.05 to 1.24 millimeters; average 1.12 millimeters; length when full fed 12 to 14 millimeters. General color very variable, from a reddish brown or olive green to black, with white to yellowish markings. Head dull black with white to yellow irregular mottlings; just below the middle of the head these markings form an almost solid transverse area; other parts of head irregularly marked, but the upper part mostly black. Dorsal surface with numerous narrow, irregular, broken, paler lines; a broad lateral area following the spiracles pale with numerous longitudinal darker markings; an adjacent area just dorsal to this often the darkest part of body; ventral abdominal surface with a broad longitudinal band of pale yellow to white, broadening out to nearly the width of the body from the sixth to anal segments; thoracic legs and prolegs concolorous with adjacent body color to somewhat paler. Tubercles small except for two large ones on the enlarged dorsal portion of the eighth abdominal segment; dark at center; setæ short, dark.

Many variations from the types described above occur. Some have a few to numerous dark spots on the dorsum and sides, especially on the second, third, and fourth abdominal segments.

Fifth stage.—Width of head 1.54 to 1.93 millimeters, average 1.72 millimeters: length when full grown 18 to 22 millimeters. Color and markings extremely variable; general color may be a reddish to a yellowish brown, a yellowish green, a dark blue-black, or any intermediate color. Head dirty white, mottled with brown, the relative proportions of each being variable, the upper half usually containing a greater amount of the darker color, with a dark line along the posterior edge of the head. Body lines irregular, varying in color from pale green or brownish yellow to white; just below the spiracles a well-defined, narrow, irregular pale line; from spiracles to center of dorsum are numerous lines, irregular, considerably broken, very numerous and distinct in some individuals, to some extent missing in others; usually the area between the two lines next above the spiracles is quite dark. Often the space between the lines just above and below the spiracles is fairly pale, the entire area forming a broad lateral longitudinal band. Ventral surface of abdomen with a broad longitudinal median line of pale yellowish green, which in many cases broadens out from the 6th to anal segment; central part of ventral surface of thorax green; thoracic legs paler than body, sometimes tinged with red in places; prolegs concolorous with body to paler; tubercles for the most part inconspicuous; two on dorsum of eighth abdominal segment raised, black in dark colored individuals and concolorous with body, except at bases of setæ, in lighter colored individuals. Setæ short, spiracles dark-margined. Behind abdominal spiracles are often swellings, each usually bearing an irregular black spot partially enclosing a smaller irregular spot of white.

Besides those already mentioned, numerous other irregular fine lines, dottings, and mottlings are found in many individuals.

PUPA.

Length 7 to 10 millimeters, not as stout as pupa of *Alsophila pometaria*. General color brown; wingpads greenish brown at first, turning brown later; surface pitted; last segment with a spine, which may be simple, or slightly forked at the end; abdominal spiracles somewhat raised, except those on eighth abdominal segment (Pl. III, E).

MOTH.

The following description has been condensed from Riley (*24*).

Male (Pl. III, B).—Wing expanse from 21 to 32 mm. Palpi very short, but distinctly two-jointed. Antennæ with not quite 40 joints, the longest twice as wide as long, each with two pairs of hair fascicles. Abdomen with first seven joints bearing each two transverse dorsal rows of stiff, reddish spines, pointed posteriorly. Wings delicate, silky, semitransparent, transversely striate, the scales short and very loosely attached. Upper surface of front wings brownish gray, crossed by three jagged, dark lines, sometimes obsolete except on the submedian and median veins, and on the costa, where they are always distinct and divide the wing into four subequal parts. A pale, jagged, subterminal band, corresponding in some degree to the outermost band in *A. pometeria*, but running out to apex, where it is always sharply relieved posteriorly by a dark mark, and often the whole length by dusky shadings. Hind wings pale ash or very light gray, with a dusky discal dot. No white band, and rarely any marginal dots. Under surface with a more or less distinct dusky spot on each wing, the front wing having in addition a dusky line along median vein and spot on costa towards apex. No pale bands.

Female (Plate III, C).—Length 5 to 9 mm. Antennæ generally with but few more than 30 joints, the longest about three times as long as wide, faintly constricted in middle, and pubescent. Body and legs pubescent, clothed with whitish and brown or black dentate scales or hairs; general coloration not uniform. Crest of prothorax and mesothorax black. A black stripe along the middle of the back of the abdomen, often interrupted on the 2d to the 7th segments, with a whitish patch each side of its front end. Abdomen tapering rather acutely behind. Two rows of spines on back of the first seven joints, more prominent than in the male, and often giving the dorsum a reddish aspect.

SEASONAL HISTORY AND HABITS.

EMERGENCE OF MOTHS.

The moths of the spring species emerge in early spring, very soon after the frost is out of the ground, and may occasionally leave the ground when warm periods occur during mild winters. Table 9 gives data concerning the emergence of moths in 1920 and 1921. Emergence in 1920 was from larvæ collected in various stages in the field the preceding spring and allowed to enter the ground normally. The 1921 records are partly from similar material, and partly from pupæ obtained from insectary material and later placed in the cages. Mortality was evidently high among the pupæ in the ground during the season of 1920–21, as evidenced by the extremely light emergence in the spring of 1921, when only 9 moths emerged from 157 larvæ and pupæ placed in the cages.

TABLE 9.—*Emergence of moths of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

IN 1920.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Maximum.	Minimum.	Average.	
			°*F.*	°*F.*	°*F.*	
Mar. 27	1	....	58	39	46.4	Clear.
Mar. 28	....	....	64	35	47.3	Do.
Mar. 29	3	3	51	35	44.5	Rain.
Mar. 30	1	1	55	36	43.5	Clear.
Mar. 31	1	2	68	38	50.5	Do.
Apr. 1	2	....	57	36	44.5	Do.
Apr. 2	....	....	40	35	36.9	Rain.

TABLE 9.—*Emergence of moths of the spring cankerworm, Wallingford, Conn., 1920 and 1921*—Continued.

IN 1920—Continued.

Date.	Emergency.		Temperature.			Remarks
	Male.	Female.	Maximum	Minimum.	Average.	
			°F.	°F.	°F.	
Apr. 3	1	1	60	31	46.2	Clear.
Apr. 4	1		44	34	39.2	Rain.
Apr. 5	1		51	35	39.5	Do.
Apr. 6			38	30	33.5	Clear.
Apr. 7	2		45	30	36.0	Rain and snow.
Apr. 8			34	26	29.7	Clear.
Apr. 9			37	23	30.2	Cloudy.
Apr. 10	1	1	47	24	34.2	Clear.
Apr. 11	1	1	54	28	40.6	Do.
Apr. 12	2		49	30	41.8	Rain.
Apr. 13	2	1	51	35	45.1	Do.
Apr. 14	1	3	49	33	40.4	Clear.
Apr. 15		5	56	30	44.5	Do.
Apr. 16			48	38	43.1	Rain.
Apr. 17			48	39	41.8	Do.
Apr. 18			59	33	45.7	Clear.
Apr. 19		2	65	34	50.3	Do.
Apr. 20			71	41	54.2	Do.
Apr. 21			47	43	44.9	Rain.
Apr. 22			63	44	51.8	Clear.
Apr. 23			59	43	48.9	Rain.
Apr. 24			53	37	46.5	Clear.
Apr. 25		1	56	35	45.8	Do.

IN 1921.

Date.	Male.	Female.	Maximum	Minimum.	Average.	Remarks
Mar. 17	1	2	52			Clear.
Mar. 18			40	25	35.6	Do.
Mar. 19	1		44	19	33.4	Do.
Mar. 20	1		74	43	56.4	Do.
Mar. 21		1	84	43	59.0	Rain.
Mar. 22			47	30	39.5	Clear.
Mar. 23			49	25	35.4	Do.
Mar. 24		2	48	27	39.0	Rain.
Mar. 25			68	49	57.2	Cloudy.
Mar. 26			67	42	51.8	Rain.
Mar. 27			69	51	56.2	Clear.
Mar. 28			70	34	51.4	Do.
Mar. 29			37	25	30.7	Do.
Mar. 30			44	20	32.9	Do.
Mar. 31			60	35	48.2	Rain.
Apr. 1		1	48	35	40.5	Do.

ACTIVITY OF THE MOTHS.

For the most part the habits of the moths are similar to those of the fall species. On leaving the ground the wingless females proceed to a near-by tree, slowly ascend the trunk, and make their way out to the smaller branches. The period of greatest activity occurs at dusk, and at this time mating usually occurs. During the day the moths are for the most part sluggish and inactive, usually passing the time under bark or concealed in other places, although the male moths are sometimes seen on the wing on cloudy or foggy days.

In from 2 to 6 days after emergence the female moths begin laying eggs, and may continue oviposition for as long a period as 10 days, although the greater part of the eggs are usually deposited during the first few days of oviposition. The moth lays the eggs in concealed places, to some extent on the main trunk, but for the most part on the smaller branches, and sometimes deposits them well out toward the tips of the twigs. In any event, they are hidden carefully

under flakes of bark, or in crevices or cracks, wherever such are found. The flexible and protrusible terminal segments of the abdomen are used as an ovipositor, which is capable of thrusting the eggs into very small crevices and quite a distance into the deeper and more extensive cavities. When placed under a bit of bark which has become somewhat loosened, the eggs are usually stuck to the inner surface of the bark, rather than to the outer surface of the wood from which it has separated. In some cases the eggs are placed in compact clusters; in others they are apparently thrust in at random. The greatest number of eggs laid by any female in captivity in the insectary at Wallingford was 250, which hardly represents the egg-laying capacity of the average moth. As the result of dissections, Wellhouse (*36*) records finding an average of 401 eggs each in the abdomens of 12 moths, and one of them contained 676 eggs.

In the protection of the insectary cages, most of the moths lived from one to two weeks, one female living 24 days. Under field conditions the length of life is probably not so great.

INCUBATION OF EGGS.

The incubation period varies to a considerable extent, the earliest laid eggs usually being subjected to cool weather which retards the development of the embryo larva. For this reason, hatching is likely to cover a shorter period of time than egg-laying. Table 10 gives data regarding incubation of eggs in 1920 and 1921.

TABLE 10.—*Incubation of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

IN 1920.

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
			Days.				*Days.*
Mar. 31	May 17	14	47	Apr. 15	May 20	26	35
Do	May 18	40	48	Do	May 22	1	37
Do	May 19	2	49	Apr. 21	May 21	14	30
Apr. 1	May 18	8	47	Do	May 22	42	31
Do	May 22	1	51	Do	May 23	37	32
Apr. 2	May 18	33	46	Do	May 24	11	33
Do	May 19	7	47	Apr. 22	May 22	3	30
Apr. 5	May 18	36	43	Do	May 23	15	31
Do	May 19	9	44	Do	May 24	28	32
Apr. 12	do	19	37	Do	May 25	7	33
Do	May 22	1	40				
Apr. 13	May 19	9	36	Maximum period			51
Do	May 20	25	37	Minimum period			30
Do	May 21	4	38	Average period			37.9
Apr. 15	May 19	24	34	Total individuals, 416.			

IN 1921.

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
Mar. 19	Apr. 24	2	36	Mar. 21	Apr. 28	2	38
Do	Apr. 25	5	37	Mar. 25	Apr. 27	6	33
Do	Apr. 26	4	38	Mar. 26	do	8	32
Do	Apr. 27	3	39	Do	Apr. 28	4	33
Do	May 2	1	44	Mar. 27	Apr. 23	1	27
Mar. 20	Apr. 22	1	33	Do	Apr. 24	2	28
Do	Apr. 23	7	34	Do	Apr. 25	13	29
Do	Apr. 24	78	35	Do	Apr. 26	2	30
Do	Apr. 25	105	36	Do	Apr. 27	2	31
Do	Apr. 26	5	37	Do	Apr. 28	94	32
Mar. 21	Apr. 25	11	35	Do	Apr. 29	9	33
Do	Apr. 26	13	36	Do	Apr. 30	1	34
Do	Apr. 27	1	37	Mar. 28	Apr. 28	32	31

TABLE 10.—*Incubation of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921*—Continued.

IN 1921—Continued

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
			Days.				*Days.*
Mar. 28	Apr. 29	29	32	Apr. 3	Apr. 29	2	26
Do	Apr. 30	1	33	Do	Apr. 30	3	27
Do	May 1	1	34	Do	May 1	3	28
Mar. 31	Apr. 29	3	29	Do	May 2	1	29
Do	May 1	1	31	Apr. 4	...do....	5	28
Apr. 1	Apr. 28	1	27	Do	May 3	7	29
Do	Apr. 29	58	28	Apr. 5	May 6	3	31
Do	Apr. 30	1	29	Do	May 8	1	33
Apr. 2	Apr. 29	10	27				
Do	Apr. 30	4	28	Maximum period			44
Do	May 1	2	29	Minimum period			26
Do	May 2	1	30	Average period			32.7
Do	May 3	1	31	Total individuals, 550.			

TIME OF HATCHING OF THE EGGS.

The eggs of the spring cankerworm hatch at approximately the same time as those of the fall species. Just before hatching, the eggs turn dark, almost black. Table 11 gives hatching records for 38 egg masses collected in the field early in April, 1920, and for 19 egg masses laid in the insectary in 1921. The spring of 1920 was unusually late, while that of 1921 was equally early, giving a difference of about four weeks in the two seasons.

TABLE 11.—*Hatching of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

FROM 38 EGG MASSES COLLECTED IN THE FIELD IN 1920.

Date.	Number of eggs hatched.	Temperature.			Date.	Number of eggs hatched.	Temperature.		
		Maximum.	Minimum.	Average.			Maximum.	Minimum.	Average.
		° F.	° F.	° F.			° F.	° F.	° F.
May 14	30	54	45	48.7	May 20	70	76	51	61.1
May 15	58	64	46	54.8	May 21	3	59	53	56.0
May 16	205	71	43	58.1	May 22	21	66	48	55.2
May 17	217	74	47	60.6	May 23	10	58	46	51.3
May 18	78	71	46	58.0	May 24	4	66	47	53.2
May 19	59	75	45	58.8					

FROM 19 EGG MASSES LAID IN THE INSECTARY IN 1921.

Date.	Number of eggs hatched.	Maximum.	Minimum.	Average.	Date.	Number of eggs hatched.	Maximum.	Minimum.	Average.
Apr. 20	2	73	36	54.0	Apr. 30	10	58	49	53.8
Apr. 21	47	76	49	60.5	May 1	7	52	44	47.5
Apr. 22	10	78	49	60.9	May 2	8	68	42	52.4
Apr. 23	8	64	45	52.2	May 3	8	70	47	55.8
Apr. 24	82	67	42	54.3	May 4	....	64	48	54.8
Apr. 25	134	76	47	59.2	May 5	....	47	44	45.1
Apr. 26	24	73	44	57.6	May 6	3	49	45	47.0
Apr. 27	20	68	51	58.4	May 7	....	62	41	51.0
Apr. 28	133	73	56	64.0	May 8	1	73	45	56.9
Apr. 29	111	72	51	59.8					

LARVAL HABITS.

The habits of the spring cankerworm larvæ are very similar to those of the fall species. On hatching, the young caterpillars proceed to the unfolding foliage and feed here and there, at first eating the tissue on only one side of the leaf, leaving the portion opposite to die and turn brown. Soon the feeding extends through the leaf in the form of tiny punctures. The small worms often feed among the opening blossom buds. As the larvæ grow, the feeding areas increase in size, but the midribs and larger veins are left untouched, and have a frayed edge of ragged leaf tissue. When the infestation is light, the larvæ in their wandering distribute their feeding so that the injury is not conspicuous. When disturbed, the larvæ either spin down on threads or raise the anterior portion of the body, taking on the appearance of a short twig, or spur. When very small larvæ spin down on threads, they are often blown to an adjacent tree. When at rest, the larvæ of the spring cankerworm have a tendency to spend their time on a twig which they closely resemble in color, while the fall cankerworm larvæ, which are usually green, are much more likely to conceal themselves on a green shoot, or in the curl of a leaf.

NUMBER OF INSTARS.

All spring cankerworms under observation at Wallingford passed through five larval instars.

LARVAL FEEDING PERIOD.

Tables 12 and 13 give data relative to the larval feeding period for 96 larvæ during the season 1921. Table 14 gives the records of the average larval feeding period by instars for 1920 and 1921. The difference in the two seasons probably explains the difference in the feeding periods. The spring of 1920 was unusually late, but after the eggs had finally hatched, the weather was warm, and favorable to rapid larval development. On the other hand, the spring of 1921 was unusually early, causing an abnormally early hatching of the eggs, but the period immediately following hatching failed to continue as warm as it had been at the start. The average daily mean temperature during the larval feeding period in 1920 was 61.9° F., while that during the same period in 1921 was 57.9° F., an average difference of 4 degrees, which explains for the most part the longer feeding period in 1921.

TABLE 12.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921.*

Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.	Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.
Apr. 21	May 22	3	31	Apr. 24	May 24	1	30
Do	May 23	2	32	Do	May 25	3	31
Do	May 25	2	34	Do	May 26	1	32
Do	May 26	1	35	Do	May 27	1	33
Do	June 1	1	41	Do	May 28	3	34
Apr. 22	May 30	1	38	Do	May 29	1	35
Do	May 31	1	39	Do	May 30	1	36
Apr. 23	June 6	1	44	Do	May 31	2	37

TABLE 12.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921*—Continued.

Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.	Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.
Apr. 24	June 4	1	41	Apr. 27	June 4	1	38
Apr. 25	May 26	1	31	Do	June 5	1	39
Do	May 27	2	32	Apr. 28	May 28	6	30
Do	May 28	1	33	Do	May 29	14	31
Do	May 29	4	34	Do	May 30	3	32
Do	May 30	3	35	Do	May 31	6	33
Do	May 31	2	36	Do	June 1	5	34
Do	June 1	1	37	Do	June 2	1	35
Do	June 5	2	41	Do	June 7	1	40
Do	June 6	1	42	Apr. 29	June 1	1	33
Apr. 26	May 29	1	33	Do	June 2	1	34
Do	May 30	2	34	Apr. 30	do	1	33
Do	June 4	1	39	May 1	May 30	1	29
Do	June 5	1	40	May 2	June 5	1	34
Apr. 27	May 30	1	33	May 3	June 2	1	30
Do	May 31	1	34	Do	June 3	1	31
Do	June 1	1	35				

TABLE 13.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921. Summary of Table 12.*

Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.
29	1	33	12	36	3	39	3	42	1
30	8	34	19	37	3	40	2	43	0
31	22	35	7	38	2	41	4	44	1
32	8								

Total larvæ, 96.
Average feeding period, 33.7 days.

TABLE 14.—*Larval feeding period of the spring cankerworm, by stages, Wallingford, Conn., 1920 and 1921.*

Stage.	1920		1921	
	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.
First	252	7.75	196	9.87
Second	226	3.73	164	6.44
Third	201	3.66	139	5.19
Fourth	152	5.66	118	5.19
Fifth (to end of feeding)	158	5.31	96	6.80
Total feeding period		26.11		33.49

ENTERING THE GROUND.

As with the fall cankerworm, the larvæ enter the ground for pupation to a depth varying from one to several inches. Only a few threads of silk are spun in the pupal cell, and no cocoon is formed. Table 15 gives the dates on which the larvæ were entering the ground in 1920 and 1921.

TABLE 15.—*Entrance into ground of larvæ of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

1920				1921					
Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.
June 10....	2	June 17....	9	May 22....	3	May 29....	20	June 5.....	5
June 11....	3	June 18....	1	May 23....	2	May 30....	12	June 6.....	2
June 12....	25	June 19....	0	May 24....	1	May 31....	12	June 7.....	1
June 13....	47	June 20....	2	May 25....	5	June 1.....	9		
June 14....	23			May 26....	3	June 2.....	4	Total....	96
June 15....	16	Total....	158	May 27....	3	June 3.....	1		
June 16....	30			May 28....	10	June 4.....	3		

PREPUPAL PERIOD.

The time elapsing between the entrance of the larva into the ground and pupation has varied from 4 to 12 days, with an average period of 6.68 days in 1920 and 7.03 days in 1921.

NATURAL CONTROL.

One outstanding feature of cankerworm history is the recurrence of extremes of abundance and scarcity. In many cases the periods of extreme abundance have been suddenly terminated by an almost total disappearance of the worms, followed by a period of comparative freedom from attack. In his original account Peck (*2*) records an almost complete disappearance of the worms between 1794 and 1795. One of the early agricultural papers notes that the worms "run out in three years." Unfortunately many of the outbreaks have not "run out" at the end of 3 years, but have increased in severity for as long as 8 or 10 years before natural causes have put an end to them, for the time being at least. During the periods of scarcity, the worms usually increase in numbers more or less steadily, although for the most part unobserved, until they again appear in great numbers.

The records are frequently obscured by accounts of outbreaks of a local nature independent of the general waves of abundance and scarcity. The records of outbreaks previous to 1875 are especially hard to interpret owing to the confusion of the two species, making it difficult to tell whether successive outbreaks consisted of the same or of different species.

A detailed discussion of the various factors connected with the natural control of the cankerworm follows.

WEATHER CONDITIONS.

Weather conditions have often been given the credit for the sudden disappearance of the cankerworms. Peck (*2*) noted that the 17th of May, 1794, was so cold that ice one-third of an inch thick was produced. This temperature was apparently fatal to the larvæ, with the result that practically no moths could be found the following year. This freeze evidently occurred just after all the larvæ had hatched. In a communication to the New England Farmer

dated June 7, 1826, Roland Howard (*7*) relates that after a period of abundance from 1806 to 1809, practically no worms were present in 1810, which was attributed by some to a severe storm soon after the worms had hatched. It seems likely that either cold, stormy weather, or extreme cold unaccompanied by rain, especially if this occurs soon after the larvæ have hatched, may be fatal to them.

Wet weather also favors the development of wilt diseases, but these do not seem to have been at any time prevalent enough to account for the sudden disappearance of the cankerworms.

DISEASES.

Peck noted that some of the larvæ were attacked by a disease which he called "deliquium," evidently referring to one of the wilt diseases which commonly attack lepidopterous larvæ. Wellhouse (*36*) records finding a wilt disease killing some larvæ of the spring cankerworm in Kansas. Sherman (*39*), reporting on a severe outbreak of the fall species in the mountains of North Carolina, which had been in progress for four seasons, stated that fungous and bacterial diseases were not much in evidence "although warm and damp weather was not lacking. Only an occasional worm was found which seemed to have perished from disease and there was no hint of an epidemic among them." Under crowded conditions and in the confined air of some of the rearing cages used for miscellaneous material in the insectary at Wallingford, a very few larvæ were attacked by some form of "wilt" disease, but no infected larvæ were found under field conditions. The cankerworms do not seem to be as subject to wilt diseases as are many caterpillars, especially the colonial forms.

STARVATION.

In a letter to the Western Rural of June 23, 1866, Sanford Howard (*12*), secretary of the Michigan Board of Agriculture, suggested among other things that the cankerworm may have been present in such numbers that the available foliage was not sufficient to carry them to maturity. It seems entirely conceivable that under certain conditions the larvæ might be numerous enough to exhaust all available foliage by the time they were only partially grown. In such a case very few larvæ would be successful in reaching maturity, and the infestation would be greatly reduced the following season. Naturally, starvation in this manner could occur only where the cankerworms were exceptionally abundant.

BIRDS.

Because the cankerworm larvæ feed in exposed locations, and are not protected by hairs or other repellent devices, they are a favorite food with many of our common birds. Work done by Forbes (*22*) in Illinois indicated that when the cankerworms became unusually abundant, many different species of birds ate enormous numbers of them. Chickadees have been found with large numbers of the eggs of the fall cankerworms in their crops (*28*). Even specimens of the much-despised English sparrow have been found with their crops full of cankerworm larvæ. Practically all of our common birds have been recorded at one time or another as cankerworm feeders,

and no attempt will be made to present a complete list. Besides feeding on the larvæ, such birds as are present in the late fall and early spring prey upon the moths as they emerge and make their way up the trees. Birds seem to be among the most important of the enemies of the cankerworms.

INSECT ENEMIES.

PREDATORS.

The following beetles have been recorded as feeding on cankerworm larvæ: *Calosoma willcoxi* Lec., *C. frigidum* Kirby, *C. calidum* Fab., and *C. scrutator* Fab. In addition, Forbes (*23*) found spring cankerworm remains in the intestinal tracts of the following carabid beetles in Illinois: *Galerita janus* Fab., *Calathus gregarius* Say, *Evarthrus sodalis* Lec., *Chlaenius diffinis* Chd., *Harpalus caliginosus* Fab., and *Harpalus pennsylvanicus* De Geer. The pentatomid bug *Podisus modestus* Dall., a mirid (*Lygus* sp.), two species of ants, a species of Panorpa, and the rapacious soldier-bug (*Sinea diadema* Fab.) have all been recorded as feeding on cankerworm larvæ.

The fraternal potter-wasp (*Eumenes fraternus* Say) has been known to store her nest with 20 cankerworm larvæ (*14*).

This list of predators could doubtless be extended to include many other predacious insects, particularly those having general feeding habits, which probably do not refuse any cankerworms they may chance to find.

PARASITES.

A number of insect parasites of the cankerworms have been recorded. In the vicinity of Wallingford, Conn., neither species has been very severely parasitized, although several different parasites have been reared in small numbers. The recorded parasites of both species of cankerworms are noted below, together with a few observations made at Wallingford.

Telenomus gnophaelae Ashm.—This was recorded by Girault (*31*) as a parasite of the eggs of the fall cankerworm. A. B. Gahan, of the Bureau of Entomology, however, has expressed some doubts as to the correctness of this determination, as none of the specimens which he has had from cankerworm eggs agree with Ashmead's type of *gnophaelae*.

Telenomus sp.—In 1919, 80 adults of a species of Telenomus emerged from 2 of 32 fall cankerworm egg masses under observation at Wallingford. The following year no egg parasites were reared. Sherman (*39*) reports that a species of Telenomus has been reared in numbers from eggs of the fall cankerworm in the mountainous regions of North Carolina.

Platygaster sp.—In 1840 Herrick (*8*) reared a species of egg parasite in considerable numbers from the eggs of the fall cankerworm, and expressed the opinion that it belonged to the genus Platygaster. As far as can be determined, no parasite of the eggs of the fall cankerworm since reared has been referred to that genus, and A. B. Gahan states that there can be little doubt that what Herrick had was in reality a Telenomus.

Meteorus hyphantriae Riley.—A few cocoons of *Meteorus hyphantriae* were found in trays containing nearly full-grown larvæ of the

fall and spring species, respectively, collected near Wallingford during the spring of 1919.

Rogas sp.—Occasionally third-instar larvæ of the fall cankerworm were found near Wallingford parasitized by a species of Rogas, their dried and shrunken skins serving as shelters for the parasite pupæ. Harrington (*25*) reports finding a number of larvæ in a similar condition, but all were infested with secondary parasites, determined as *Hemiteles sessilis* Prov.

Euplectrus sp.—One third-instar fall cankerworm larva was found near Wallingford on June 5, 1919, collapsed and doubled over a greenish parasite larva which was constructing its cocoon. The adult parasite emerged two weeks later. Payne (*37*) reports from Nova Scotia the rearing of a species of Euplectrus, and Sherman (*39*) also reports a species of the same genus from the fall cankerworm from North Carolina. Both of these may be the same and identical with the parasite reared at Wallingford.

Amblyteles utilis Cresson.—*Amblyteles utilis* has been recorded as a parasite of cankerworms (*35, p. 359*).

Apanteles paleacritae Riley.—This species was described by Riley (*21*) as a parasite of the spring cankerworm and reported by Harrington from the fall species. A single adult of this species was reared by Dwight Isely, of the Bureau of Entomology, in May, 1918, at Bentonville, Ark., from a larva of the spring cankerworm. It is said that the host larva does not die until some time after the emergence of the parasite larva, which spins its cocoon on its host or a near-by leaf.

Tachinomyia sp.—Fourth-stage and sometimes third-stage larvæ of the fall cankerworm are sometimes found bearing on the head or prothorax one or more oval, flattened, creamy white tachinid eggs. On hatching, if the host larva has not molted in the meantime, the parasite larva makes its way through the skin of the caterpillar, usually on or near the head, and takes up its position just beneath. Parasitized larvæ complete their development, enter the ground, and commence the construction of their cocoons, but rarely complete them before being killed by the parasite. Out of five parasitized larvæ entering the ground at Wallingford in the spring of 1919, two flies emerged in May, 1920. These were determined by Dr. J. M. Aldrich as a species of Tachinomyia, probably undescribed.

Harris (*9*) mentioned a tachinid fly as a parasite of the cankerworm in Massachusetts, causing a mortality of one-third. Many other workers have mentioned tachinid parasites, but none seem to have been reared and determined.

Sarcophaga cimbicis Townsend or *S. latisterna* Parker.—This species was reared by Sherman from the fall cankerworm in North Carolina in 1920, and determined by Dr. J. M. Aldrich.

OTHER ENEMIES.

Coriarachne versicolor Keyserling.—Spiders determined by C. R. Shoemaker, as this species were found near Wallingford feeding on the spring cankerworm moths as they emerged.

Nothrus ovivorus Packard.—This mite was described by Packard (*13, p. 664, fig. 639*) and recorded as having been observed in the act of sucking the eggs of the fall cankerworm. As far as is known, this

initial observation has never been verified. Dr. H. E. Ewing, of the Bureau of Entomology, states that this species is unrecognized, and that the habit of sucking eggs, if it occurs, is contrary to the habits of the group to which the genus Nothrus belongs.

CONTROL MEASURES.

Three general methods have been recommended and used for the control of cankerworms: Cultivation, spraying, and the use of mechanical barriers to prevent the ascent of the wingless female moths and the larvæ.

CULTIVATION

Plowing and cultivation at any time when the spring cankerworm larvæ or pupæ are in the ground will aid materially in their control by exposing them to many of their enemies. This practice, however, will have little effect on the fall species, which is safely inclosed in a tough cocoon.

SPRAYING.

The present practice of spraying for the codling moth and other insects has almost eliminated the cankerworm as a pest in well-cared-for orchards.

Laboratory tests have shown that the larvæ of both species are readily killed by arsenate of lead, applied at the strength of 1 pound of the powdered form in 50 gallons of water. In all tests made in the laboratory at Wallingford, even the last-stage larvæ died within four or five days after being placed on sprayed foliage, and the earlier stages were killed in a shorter time.

Although the larval feeding period of the cankerworms is short, it occurs at such a time that the first two of the regular summer spray applications recommended for the apple orchard will be effective. Peck (*4*) noted that the eggs "commonly hatched about the time that the red currant is in blossom, and the apple tree puts forth its tender leaves." In Wallingford the greater part of the hatching of the eggs of the fall species has invariably occurred during the period when the apple blossoms of medium-season varieties were showing pink, and was practically completed before the blossoms were open. The eggs of the spring species began to hatch in 1920 a day or two later than those of the fall species, and the hatching period was somewhat more prolonged. It is therefore evident that if the so-called pink spray includes an arsenical, and is thoroughly applied, the newly hatched larvæ of both species will find awaiting them a meal of poison. This application is the more important of the two noted, and in case of a severe infestation should never be omitted. If an outbreak occurs in young orchards not in bearing, an application of arsenate of lead should be made shortly after the proper time for the pink spray on bearing trees, at which time all the eggs will have hatched, but comparatively little feding will have been done. Observations in an orchard near Wallingford during the season of 1920 confirmed these recommendations. The orchard in question had been totally neglected for a number of years, and had become thoroughly infested with the spring cankerworm. In 1920 the owners applied the pink spray, but were a few days late about it, al-

though it was completed before the blossoms had opened to any extent. Before the spraying was done practically every leaf was being eaten by several larvæ. A few days later it was difficult to find a living larva, and practically impossible to find a healthy one.

Quaintance (*32*) has reported almost perfect control of the spring cankerworm in two orchards in Virginia. In 1905 a single application of Paris green at the rate of 1 pound in 75 gallons of water, applied when the larvæ were one-half to two-thirds grown, caused an almost complete disappearance of the larvæ within three days. The following year part of a second orchard was sprayed twice with arsenate of lead with similar results.

No field tests were made at Wallingford with the fall species, but results equally satisfactory could doubtless be obtained.

In orchards which are well cared for, the cankerworm infestation is seldom severe, and can usually be sufficiently controlled by the calyx spray. This application is ordinarily put on about as the larvæ of both species are entering the fourth stage, and have at least 8 to 10 days yet to feed. During this time most of the larvæ present will be killed. This application alone will keep a light infestation within bounds, although it will not prevent much of the injury of the season when the application is made.

Where spraying is consistently practiced there is little complaint of cankerworm damage. In properly sprayed orchards banding and other measures for cankerworm control are seldom necessary.

MECHANICAL BARRIERS.

When for any reason spraying is impracticable, the use of various mechanical barriers, properly applied, will give complete protection. At a very early date the wingless condition of the female moths was recognized as a weak point in the life history of the cankerworm, and a number of interesting and ingenious types of barriers were devised and used in the effort to prevent the moths from ascending the trees to lay their eggs. At present the most common method of preventing the ascent of the moths is by means of sticky bands. For applying any of the commercial tree-banding materials, Doctor Britton (*33*), of the Connecticut Experiment Station, recommends the following procedure: First, place around the trunk of the tree a strip of cotton batting 2 or 3 inches wide; second, cover this with a band of tarred paper 5 or 6 inches wide, drawing it tight and tacking it at the ends, which should overlap; finally apply a smooth coat of sticky material one-eighth of an inch thick and covering about two-thirds of the width of the tarred paper. The cotton batting serves to fill any irregularities in the bark and prevents the passage of the moths under the tarred paper. The use of the tarred paper makes possible a more economical use of the sticky material than would be possible in applying it directly to the rough and irregular bark, and eliminates possible injury to the tree.

Directions for making a gipsy moth tree-banding material which has been developed at the gipsy moth laboratory at Melrose Highlands, Mass., are as follows (*38*):

Prepare a stock mixture by placing in a large kettle one part by weight of hard coal-tar pitch [melting point about 49° C.] and adding one part by

weight of coal-tar neutral oil [density of 1.12 to 1.15 at 20° C.], applying heat to the kettle until all of the pitch has melted and thoroughly mixed with the oil, then removing the kettle and adding two more parts by weight of coal-tar neutral oil and mixing the contents thoroughly. This product, known as pitch neutral-oil mixture, can be poured and worked after cooling.

The banding material is mixed as follows:

Eighteen pounds of the pitch neutral oil or stock mixture and 70 pounds of the coal-tar neutral oil are added to the mixing kettle and the stirrer started working. In a few moments 12 pounds of hydrated lime are added slowly to the mixture. When the contents have become of a uniform consistency 50 pounds of rosin oil [known as first run "kidney," having a viscosity of 52 at 100° C. tested with a Saybolt universal viscosimeter] are added and allowed to mix for a few minutes, or until the contents begin to thicken, after which 20 pounds of coal-tar neutral oil are added and the contents allowed to mix thoroughly. The stirring is then stopped and the material poured into containers and allowed to set for two or three days, and by the end of this time the material has set into a semisolid state, of somewhat softer consistency than cup grease.

For use in the cooler seasons of cankerworm emergence, the formula should be modified by the addition of a little more of the coal-tar neutral oil.

This material may be applied with a putty knife or a thin hardwood paddle directly to the tree, after first removing any loose flakes of bark. It has proved fairly effective against the cankerworm moths except in extremely heavy emergences, in which cases bands 6 inches wide were bridged and crossed in a very short time. For the cankerworm moths the most satisfactory band is one rather thin and several inches wide, rather than the narrower bands which are applied for the gipsy moth with a special gun.

The bands should be examined at intervals, particularly during the period when the moths will be likely to emerge in greatest numbers, and the surface renewed by stirring with a putty knife or paddle whenever it has been bridged by foreign matter or the bodies of moths, which, when numerous, will sometimes bridge a fairly broad band, enabling the moths emerging later to pass without becoming entangled. One may determine whether the bands are doing effective work by the use of a check band, placed above the first on a tree here and there. Some of the moths on reaching the obstruction will not attempt to pass, but will lay their eggs below it. For this reason, the band should remain effective until apple-blossom time is over in order to protect the foliage from the larvæ hatching from such eggs. In severe infestations it will pay to continue the barriers another month for the purpose of preventing the reascent of any larvæ which have dropped from the tree.

Barriers of wire, tin, or lead were formerly used to quite an extent, but they are hard to fit perfectly to the irregular surface of the tree trunk, and do not always prevent the passage of larvæ hatching from eggs laid below them. Barriers of cotton batting and other loose, fluffy material are sometimes used, but are likely to become matted down by rain, and are not on the whole as satisfactory as the sticky bands.

For the control of the fall species the bands should be in place at least by the middle of October, and remain effective until the ground is thoroughly frozen for the winter. With severe infestations they should be renewed as soon as the ground thaws with the first warm days of late winter or early spring, in order to intercept any moths whose emergence has been delayed. They should be kept effective

until the apple blossoms have fallen, when all eggs laid below them will have hatched.

For the spring species the barriers should be in place with the first thawing of the ground in February or March, and remain effective until after the apple blossoms have fallen, as indicated for the fall species.

SUMMARY.

The cankerworms have been known in this country since colonial days, but not until about 50 years ago was it realized that two species were present. They have since been known as the fall cankerworm (now *Alsophila pometaria* Harris) and the spring cankerworm (*Paleacrita vernata* Peck).

The cankerworms prefer to feed on elm and apple, but are often found on many of our common deciduous fruit, forest, and ornamental trees.

The fall cankerworm is found in greatest abundance in the northeastern part of the United States and the southeastern part of Canada, but has been reported from several of the States in the Mississippi Valley, from Colorado, and from California. The spring species is found in southern Canada as far west as Manitoba, in the northeastern and central portions of the United States as far south as Texas, and in California.

As the females are wingless, dissemination by their own efforts is slow. The larvæ of both species are sometimes caught on passing vehicles and carried to new localities. The eggs of both species, and particularly those of the fall species, are likely to be carried to new localities on nursery stock.

During periods of abundance the cankerworms do an enormous amount of damage, practically defoliating the trees they attack unless controlled. They are most likely to become abundant in neglected orchards or in shade and forest trees.

Both species have but one generation a year.

The moths of the fall cankerworm emerge from the ground mostly in late fall and early winter during warm periods after the ground has been frozen. Mating and egg laying soon occur, and the species winters in the egg stage, except in occasional instances in which the emergence of the moths is delayed until spring. The eggs hatch in the spring, during the period when the apple blossoms are in the pink. The larvæ feed for four to five weeks, passing through four stages. When through feeding they enter the ground, construct a tough cocoon, and after about a month transform to the pupa.

The spring cankerworm moths emerge almost exclusively in the spring, and lay eggs in the crevices of the bark and in similar protected locations. The hatching of the eggs and the larval feeding period coincide rather closely with those of the fall species, but the spring cankerworm passes through five larval stages. No cocoon is constructed, and pupation occurs soon after the larva has entered the ground.

The two species are readily distinguished in all stages.

The cankerworms are held in fluctuating degrees of control by an extensive array of factors, among which are unfavorable weather, birds, and parasitic and predacious insects.

Plowing during the summer and fall will aid in the control of the spring cankerworm. Both species are readily controlled by a *thorough* application of arsenate of lead in the so-called pink spray, with a second application soon after the apple blossoms have fallen. Where spraying is impracticable, satisfactory control may be obtained by the use of barriers at the proper time to prevent the ascent of the moths, and later that of the larvæ hatching from eggs laid beneath the barriers.

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STUDIES OF THE MEXICAN BEAN BEETLE IN THE SOUTHEAST

By

NEALE F. HOWARD, Entomologist, and L. L. ENGLISH, Junior Entomologist,
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CONTENTS

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STUDIES OF THE MEXICAN BEAN BEETLE[1] IN THE SOUTHEAST.[2]

By NEALE F. HOWARD, *Entomologist*, and L. L. ENGLISH, *Junior Entomologist, Truck Crop Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

Wherever it occurs the Mexican bean beetle is by far the most serious enemy of beans. It has been known for about 75 years in the Southwest, where it has undoubtedly been established for a longer period. It was long ago reported that in Colorado its possibilities as a pest were greater than those of the Colorado potato beetle. In many sections in the Southeast it is often the determining factor in the growing of beans.

The original home of this beetle is southern North America. It occurs in many parts of Mexico and in Guatemala.

The species was first discovered in the Southeast in 1920, when specimens were received at the Alabama Experiment Station from Blocton and Birmingham, Ala. Authentic reports by various growers indicate that the insect was not at all uncommon about Birmingham in 1919, and it is presumed that it reached Alabama at least as early as 1918.

It has been pointed out by Dr. W. E. Hinds that during the recent European war large shipments of alfalfa hay from the West were received in northern Alabama, and it is possible that the insect was introduced with these shipments, the infestation originating from the Southwest rather than from Mexico. In 1921 the insect was reported from Thomasville, Ga., by S. E. McClendon, the infestation indicating the presence of the beetle there for at least one year before that time.

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[1] *Epilachna corrupta* Muls.; order Coleoptera, family Coccinellidae.

[2] Report on research investigations on the Mexican bean beetle conducted during the years 1921 and 1922. During 1921 the project was carried on cooperatively with the Alabama Experiment Station.

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By the fall of 1920 the bean crop about Birmingham and Blocton Ala., was destroyed by the bean beetle. In 1921 the infestation was extremely severe, and most of the early bean crop was destroyed.

FIG. 1.—Bush snap beans destroyed by the Mexican bean beetle at Birmingham, Ala. Velvet beans adjacent were not attacked.

By August 1 there was hardly a bean field in bearing near Birmingham. (Pl. I, *A*, *B*.) Reports of severe damage came also from other points in northern Alabama.

FIG. 2.—Destruction of pole lima beans by the Mexican bean beetle at Birmingham, Ala.

In 1921 the price of snap beans and Lima beans rose to unusual levels on the Birmingham markets, owing to the practical destruction by this insect of bean plantings in the district. At Chattanooga,

Tenn., where the insect was not known to occur until 1921, the same situation occurred in 1922, one year after the insect reached that region. (Figs. 1, 2.) By the fall of 1922 practically no beans were growing about Chattanooga. Serious damage also occurred about Atlanta and other points in northern Georgia, and in many sections of eastern Tennessee.

DESCRIPTION.

The Mexican bean beetle is a robust, hard-shelled insect of hemispherical form bearing eight black spots on each elytron or wing cover. (Fig. 3; Pl. II, *A*.) Typical adults measure about one-fourth to five-sixteenths inch in length and one-fifth to one-fourth

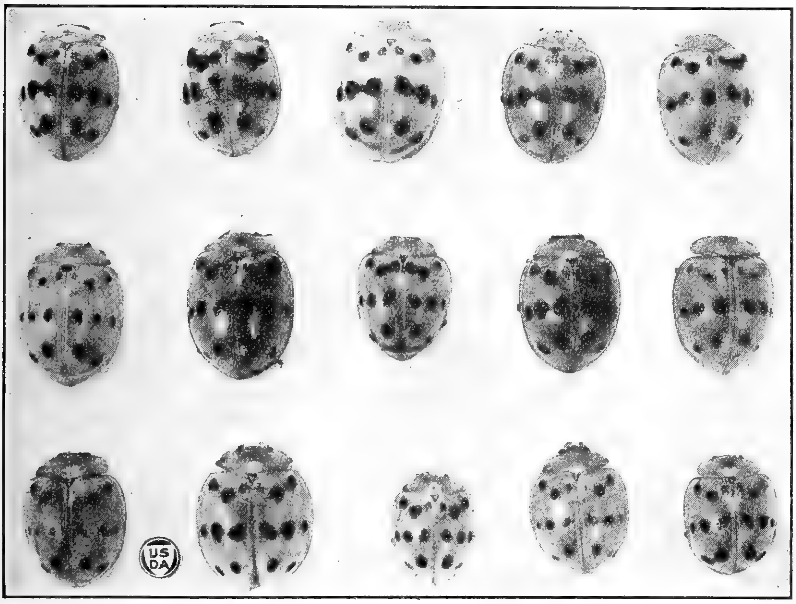


FIG. 3.—Adults of the Mexican bean beetle, showing variations in size and marking.

inch in width, and when fully mature are copper-colored. Newly emerged specimens are light lemon yellow. Males are distinguished from females by a notch in the posterior abdominal segment, this notch being absent in the females. Males average slightly smaller, but many are as large as females.

The eggs are small, about one-twentieth of an inch long, orange-colored, and are laid in masses of from 40 to 60 on the under sides of the bean leaves.

The larvæ, on hatching from the eggs, are orange-colored, and are covered with long branched spines. (Fig. 4; Pl. I, *A*.) They grow rapidly and become about one-third inch long and half as wide before pupation takes place. (Pl. II, *B*.)

The pupa is almost the size of the beetle, is yellow, and is attached to the leaf or object on which it pupates by the last larval skin, which is white and spiny and covers the posterior abdominal segments. (Pl. III, *A*, *B*.)

The Mexican bean beetle belongs to the family Coccinellidæ, or lady-birds, and all the known species in this country are beneficial except the insect under discussion and the squash lady-beetle (*Epilachna borealis* Fab.). The Mexican bean beetle has never been known to eat other insects, and it resembles more closely in many ways the family of leaf-eating beetles, or Chrysomelidæ, than the Coccinellidæ.

DISTRIBUTION.[3]

The rapid spread of the Mexican bean beetle since its introduction into the Southeast has been remarkable. In 1920, late in the summer, Dr. W. E. Hinds and coworkers found 13 counties infested in northern Alabama. In 1921 a rapid spread in all directions took place, especially to the northeast. By fall the insect was found in portions of six States, over an area of approximately 40,000 square miles, as compared with 4,500 square miles infested the previous year. The distribution in 1922 in the Southeast, so far as known, covered at least 70,000 square miles in seven States. (See map, fig. 5.)

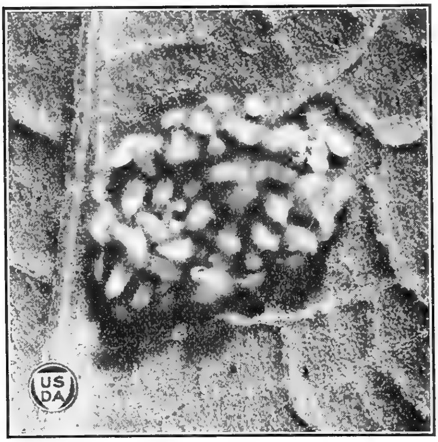


FIG. 4.—Young larvæ of the Mexican bean beetle clinging to eggshells a short time after hatching.

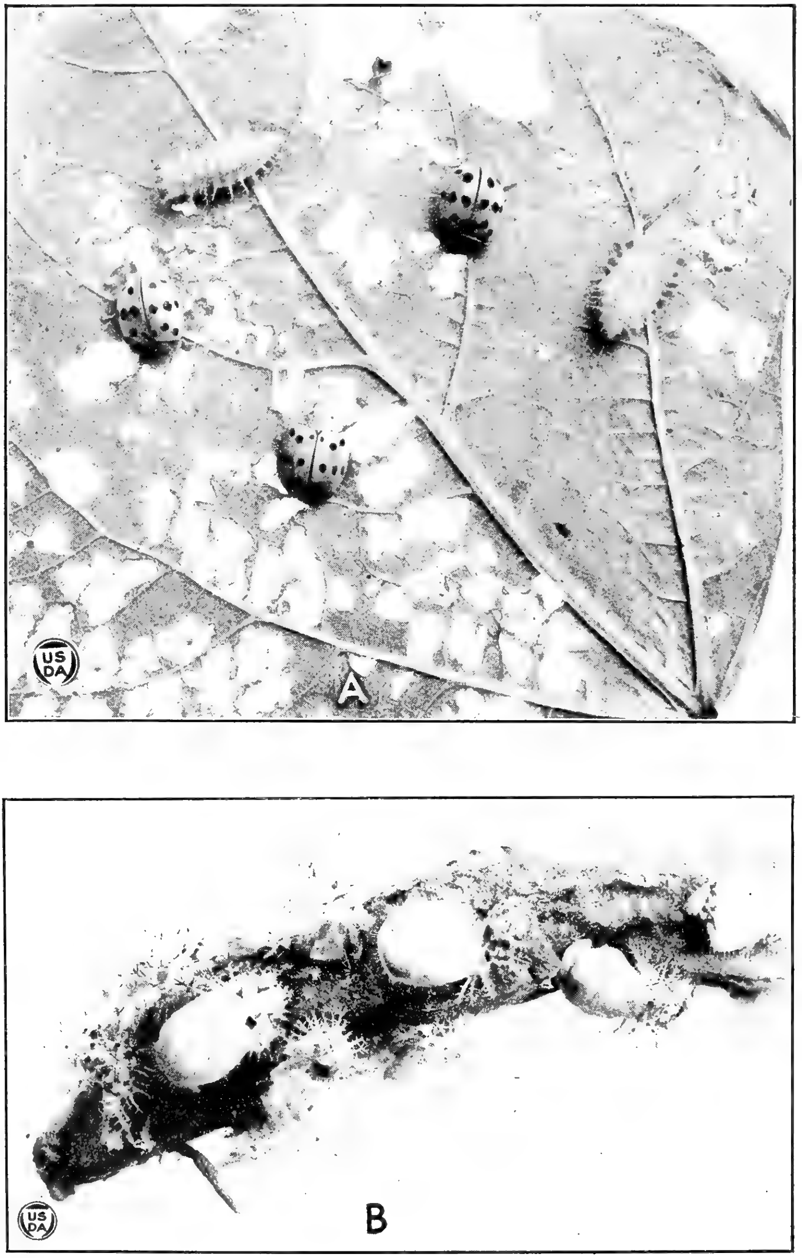
An isolated infestation was reported in 1921 at Thomasville, Ga., near the Florida line. This infestation covered 14 square miles. No appreciable spread in this locality occurred during 1922, only 3 additional square miles being infested.

The spread in general has been decidedly to the north. In the fall of 1920 the most northern locality found to be infested was Dekalb County, Ala. One year later the infestation had reached Whitley and McCreary Counties, Ky., Hawkins County, Tenn., and Greenville County, S. C., all of which points are more than 200 miles from Dekalb County, Ala. In 1922 this rapid spread continued, and the insect traversed an area 110 miles across to the northwest at its widest point, viz, from Whitley and McCreary Counties to Bullitt County, Ky. No records are available and no scouting was done in eastern Kentucky. It is certain, however, that the insect is present at least over the territory southeast of Madison, Jackson and Clay Counties. Fayette County, Ky., and Lee and Scott Counties, Va., were scouted by the Bureau of Entomology and found to be infested.

[3] Since this paper was prepared new records of spread have been received, chiefly through the cooperation of entomologists in the States concerned. The beetle is now present in the following localities in addition to those mentioned above: Ross, Gallia, Jackson, Adams, Highland, Pike, Scioto, and Franklin Counties, Ohio; Ashe, Avery, Burke, Cleveland, Gaston, Lincoln, McDowell, Polk, Rutherford, Watauga, Buncombe, Madison, and Yancey Counties, N. C.; Abbeville, Cherokee, and Spartanburg Counties, S. C.; Lamar County, Ga.; Washington and Unicoi Counties, Tenn.; Lee County, Ala.; Tishomingo and Itawamba Counties, Miss.; Spencer, Meade, Letcher, Laurel, Bell, Clay, Estill, Harlan, Leslie, Ousley, and Perry Counties, Ky.; and Russell and Wise Counties, Va.

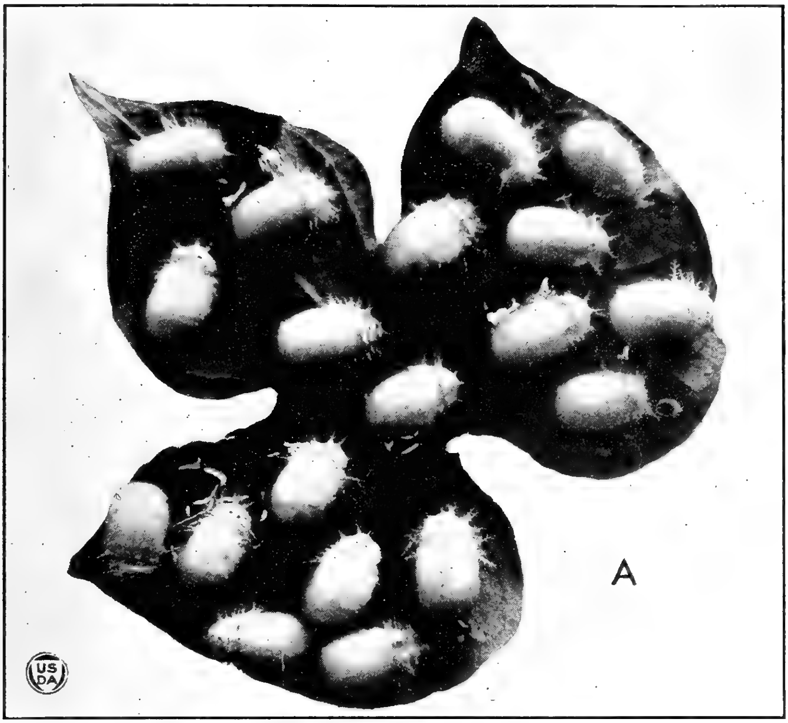
DAMAGE DONE BY THE MEXICAN BEAN BEETLE

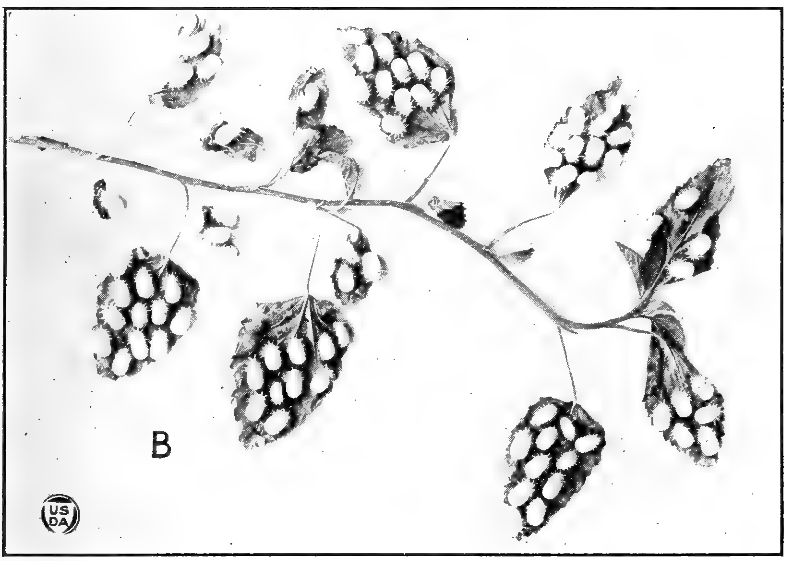
A, Field of pole Lima beans destroyed, Birmingham, Ala., 1922; *B*, bush Lima beans destroyed, Birmingham, Ala., September, 1921



ADULTS, LARVÆ, AND PUPÆ OF THE MEXICAN BEAN BEETLE

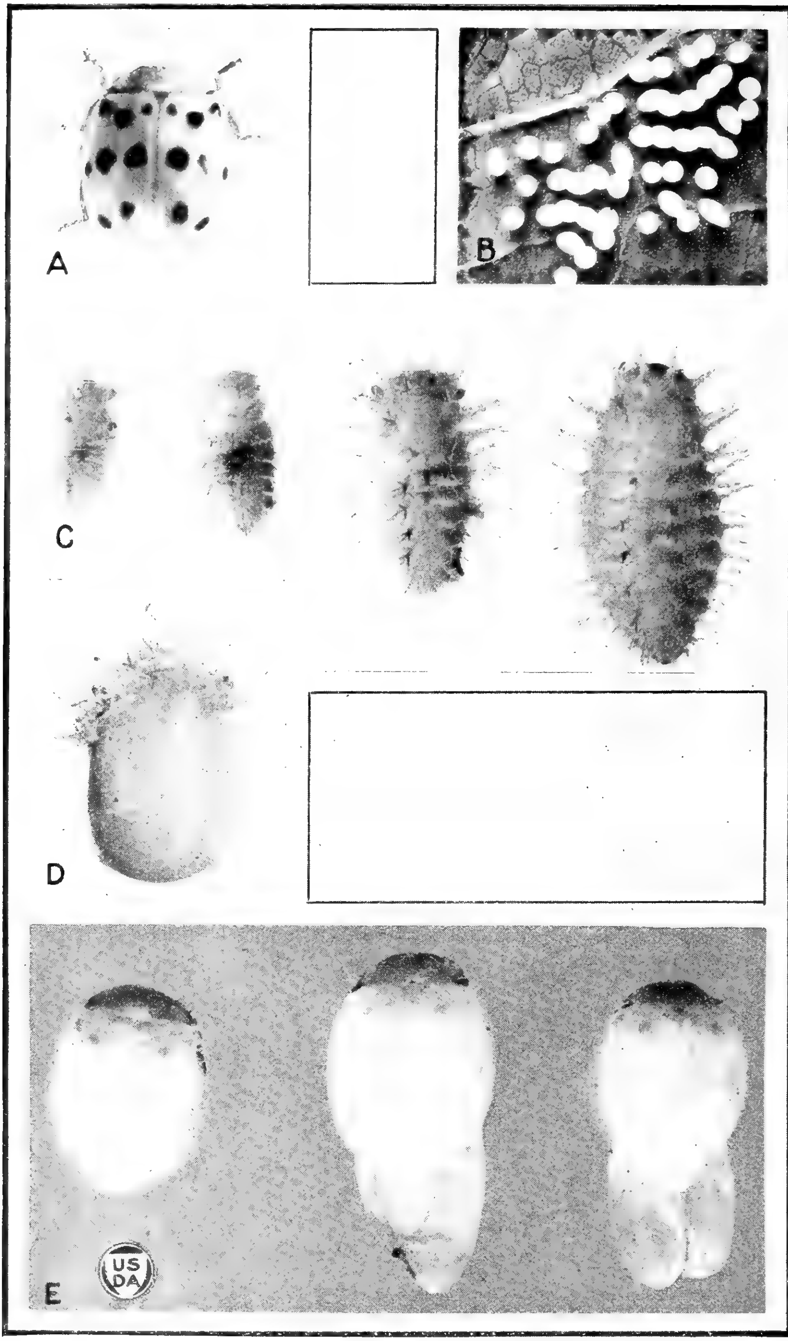
A, Adults and fourth-stage larvæ on a bean leaf; *B*, pupæ and pupal skins on a bean pod. Considerably enlarged





PUPÆ OF THE MEXICAN BEAN BEETLE

A, Pupæ on a wild morning-glory leaf from bean field, about twice natural size; *B*, pupæ on a weed from a bean field, about one-half natural size



STAGES OF THE MEXICAN BEAN BEETLE

A, Adult; *B*, egg mass; *C*, four larval stages; *D*, pupa; *E*, adults shortly after transformation from pupæ. All slightly over four times natural size

NATURAL SPREAD.

The Mexican bean beetle is capable of long flights. In the western part of the United States it must necessarily fly long distances to suitable hibernation quarters. In its newer habitat in the Southeast it migrates throughout the season, but especially in spring and fall. Experiments with marked beetles show that a flight of 5 miles is possible within two days and flights up to 3½ miles are common. Records of the spread in the Southeast indicate that much greater distances than these are traversed with ease.

Many other natural factors, of course, may contribute to the remarkable spread of the beetle, among them being air currents and

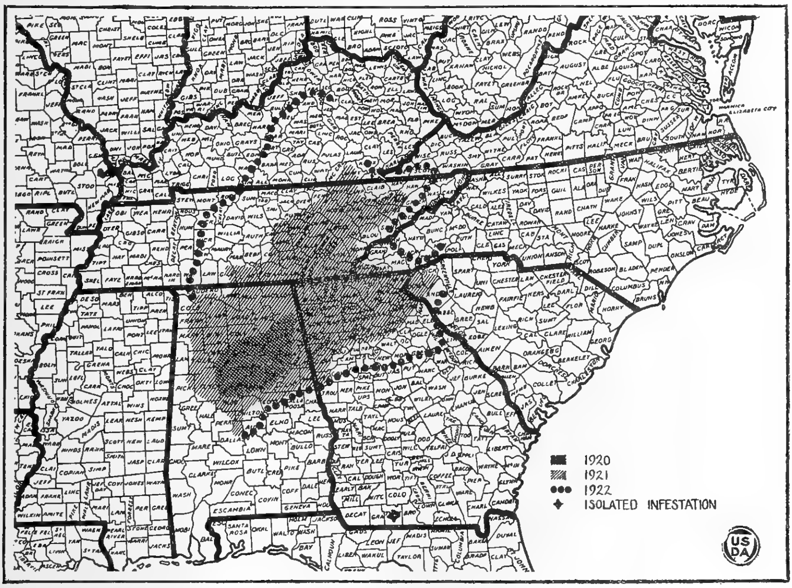


FIG. 5.—Map showing known distribution and spread of the Mexican bean beetle in the Southeast to December, 1922. The map was prepared from records obtained through the cooperation of State entomologists and others in the States concerned and chiefly from scouting done by the Bureau of Entomology under the direction of J. E. Graf and the senior author.

flood waters. It is believed, however, that the spread northward is attributable to the fact that the Mexican bean beetle is a northern Transition or sub-Boreal form, or at least is searching for conditions similar to those found in the higher altitudes of the Southwest and the Mexican plateau. No appreciable spread to the south in Alabama or south from Thomasville, Ga., nor any spread west into Mississippi, occurred during 1922. The damage to the bean crop in many instances has been extremely severe the second year after the insect has reached a new district of approximately the same latitude as Birmingham, Ala., or farther north. No reports of persistent, severe injury have come from southern points. Great damage occurred at Chattanooga, Tenn., and Atlanta, Ga., in 1922, one year after the beetle was known to have reached these places.

LIFE HISTORY AND HABITS.

The adult (Pl. IV, *A*) begins to feed immediately on arrival in the bean field from winter quarters. Females may begin to lay eggs 8 days after emergence from hibernation and possibly sooner, but the majority feed for a longer period, the average time being 14 days for 6 females in 1922. The adult feeds on the under surface, usually puncturing the leaf and leaving ragged holes, some very small, others one-fourth inch across. Only a very small percentage of feeding takes place on the upper surface.

Mating occurs in most cases in the fall, but also in the spring. The abdomen of the gravid female gradually becomes distended, and is noticeably enlarged 24 hours before oviposition. Females are then easily distinguished from males. An individual female has deposited as many as 1,669 eggs during a season. Eggs are usually laid in groups of from 40 to 60, averaging 51 for females observed by the writers in 1921 and 1922. Eggs (Pl. IV, *B*) are almost invariably placed on the under surface of the leaves in rather compact groups. In midseason a female will deposit a group of eggs quite regularly every two or three days until death.

The egg-laying records of a few representative females chosen from 69 complete experiments in 1921 and 1922 are given in Table 1. Included also is the time between emergence and the first egg laying. The beetles of the fourth generation did not lay eggs. The records of mating are the observations made while attending to the experiments and are not complete. Each experiment included a male and female, except in the cases noted.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922.*

1921.

OVERWINTERED FEMALES.

No. LH-9: Female collected in field March 26; more than 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 5	68	May 12	60	May 28	58
8	72	15	55	31	53
14	74	17	60	June 3	52
21	48	20	53	7	31
26	68	23	64		
30	72	25	54	Total	1,005
May 9	63				

No. LH4-2: Female [1] dormant from hibernation cage March 24; 42 days between removal and first eggs.

	Eggs.		Eggs.		Eggs.
May 5	61	May 24	57	June 6	54
13	56	26	58	9	57
18	57	29	58		
22	56	June 1	58	Total	572

FIRST GENERATION FEMALES.

No. LH-4G: Female emerged May 20; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
May 31	47	June 21	54	July 6	55
June 4	41	22	57	8	51
7	53	26	53	11	54
9	52	28 [2]	56	13	54
13	59	30	53		
15	55	July 2	54	Total	1,013
17	55	3 [2]			
19	55	5	55		

[1] This female had no opportunity to mate in 1921. All groups deposited were normally fertile.

[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922*—Continued.

1921—Continued.

FIRST GENERATION FEMALES—Continued.

No. LH-2G: Female emerged May 19; 16 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 4	56	June 17	54	June 27	58
8	55	19	55	28	54
9	53	21	54	30	56
11	56	22	58	July 1	58
13	56	23	53		
15	56	25	47	Total	879

SECOND GENERATION FEMALES.

No. LH-1G2: Female emerged July 5; 6 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 11 [2]	49	July 22 [2]		Aug. 2	59
11	56	23 [2]	59	5	59
13	60	25	59	6	58
14 [2]		27	57	8	62
15	60	28	60	10	57
17	65	30	57		
19 [2]	58	Aug. 1	60	Total	1,032
21	37				

No. LH-5G2: Female emerged July 16; 7 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 21 [2]	..	Aug 11	48	Aug. 30	46
22 [2]	..	12 [2]	..	31	46
23 [2]	60	13	46	Sept. 1	44
25	31	14	47	5	91
27	61	16	48	6	47
29	47	17	56	8	28
30	51	18	47	10	66
Aug. 2	28	20	46	13	43
2	68	22	48	14	55
5	47	23	46	17	47
6	48	24	44	20	46
8	49	26	49		
10	48	29	47	Total	1,669

THIRD GENERATION FEMALES.

No. LH-2G3: Female emerged August 8; 6 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Aug. 14	63	Aug. 22	61	Aug. 31	61
15 [2]	..	24 [2]	..	Sept. 1	58
16 [2]	..	25	62	3	61
17	60	26 [2]	..	5	60
18	61	27	57	8	59
19 [2]	..	29	61		
21	51	30 [2]	..	Total	775

No. LH-7G3: Female emerged September 1; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Sept. 12	75	Sept. 22	66	Oct. 11	66
13	62	23	65	21	56
15	64	26	41	29	73
17 [2]	68	28	67		
19	60	30	63	Total	955
19	66	Oct. 3	63		

1922.

OVERWINTERED FEMALES.

No. LH-8 [3]: Female emerged from hibernation cage April 4; 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 14	32	Apr. 24	29	May 4	30
15 [2]	..	26 [2]	..	9	29
17	29	27	36		
20	29	May 3	27	Total	241

[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.
[3] Pair from third generation, 1921.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922*—Continued.

1922—Continued.

OVERWINTERED FEMALES—Continued.

No. LH-16: Female emerged from hibernation cage April 5; 20 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 25	73	May 31	71	June 17	56
May 1	55	June 3	50	23	19
6	50	7	59		58
9	75	9	59		
15	67	12	57	Total	821
22	72				

FIRST GENERATION FEMALES.

No. LH-3G: Female emerged June 4; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 15	29	July 12[2]	..	July 23	52
22	55	13	54	27	14
July 5	7	15[2]	..	28	35
6[2]	..	17	32	Aug. 1	56
8	54	20	51		
11	58	22[2]	..	Total	497

No. LH-5G: Female emerged June 5; 14 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 19	55	July 11	63	July 18	54
July 4	57	14	59		
8	57			Total	345

SECOND GENERATION FEMALES.

No. LH-3G2: Female emerged July 19; 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 29	43	Aug. 14	57	Aug. 29	50
Aug. 1	54	17	54	Sept. 1	55
3	53	18	59	3	55
6	54	21	57	6	55
9	52	25	23		
12	50	27	55	Total	826

No. LH-5G2: Female emerged July 24; 8 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Aug. 1	41	Aug. 18	55	Sept. 6[2]	..
2	60	20	61	7	60
5	60	22	62	9	60
7	64	24	63	17	50
9	65	26	64	18[2]	..
12	40	29	60	20	61
14	62	Sept. 1	51	27	52
15[2]	..	3	62		
17[2]	..	5	61	Total	1,214

THIRD GENERATION FEMALES.

No. LH-2G3: Female emerged August 26; 14 days between emergence and first eggs.

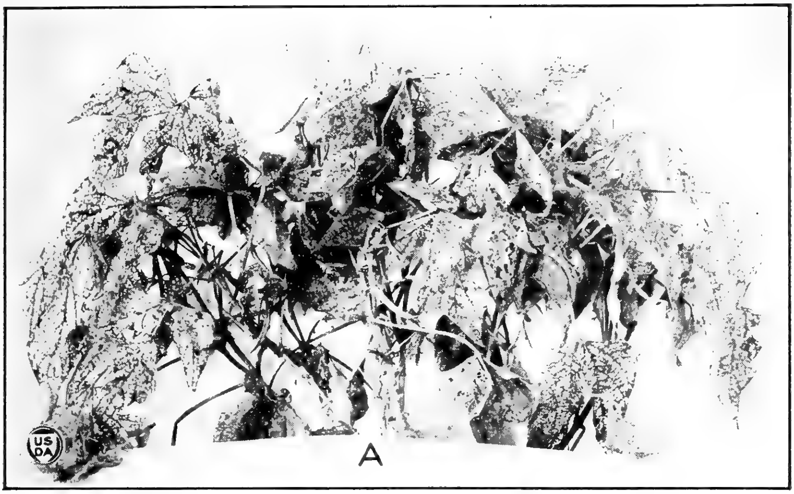
	Eggs.		Eggs.		Eggs.
Sept. 5[2]		Sept. 20	64	Oct. 9	55
9	62	23	63	24	47
11	60	26	55	Nov. 8	58
14	64	30	68		
17	54	Oct. 3	58	Total	708

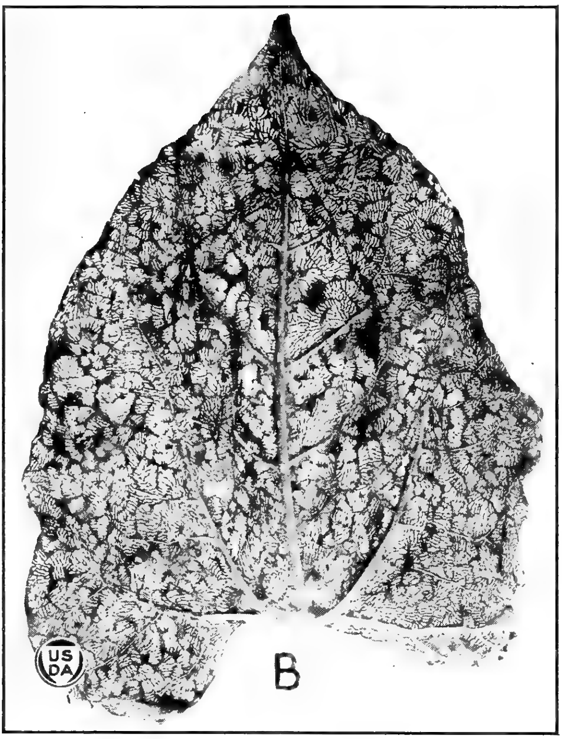
No. LH-3G3: Female emerged August 31; 15 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Sept. 15	62	Oct. 3	63	Nov. 13	67
19	30	9	63		
24	61	24	60	Total	524
27	65	Nov. 2	53		

[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.

The average number of eggs laid by all the females for which records are complete for the two seasons is shown in Table 2.





LARVAL FEEDING OF THE MEXICAN BEAN BEETLE

A, Bush bean plant destroyed by larvæ; *B*, bean leaf showing characteristic feeding

DESTRUCTION OF BEANS CAUSED BY THE MEXICAN BEAN BEETLE

A, Beans destroyed by Mexican bean beetle (note contrast with younger beans not destroyed, to the left); *B*, same field as shown in *A* after rain and wind had beaten leaves from plants

TABLE 2.—*Eggs laid by 69 females of the Mexican bean beetle for which records are complete, 1921 and 1922.*

Generation.	1921		1922	
	Number of females.	Average number of eggs per female.	Number of females.	Average number of eggs per female.
Overwintered generation	10	507	15	252
First generation	4	708	11	286
Second generation	5	1,272	8	479
Third generation	12	413	4	422
Average for 69 females (two seasons)				459

Some females laid no eggs and others only one or two groups, but these are included in the above averages. The average for all females as given is probably low, for in nature some of the overwintered females may have deposited eggs the preceding fall, and some of the third and fourth generation females, and a very small number of the second generation, might have deposited eggs the ensuing spring.

Of 15,804 eggs laid in cage tests in 1921, 46.7 per cent hatched. Of 7,024 eggs deposited in 1922, 52.5 per cent hatched. The lower percentage in 1921 was due in part to the very low percentage of eggs hatching which were laid during the high temperature of August.

The Mexican bean beetle is polygamous. A single fertilization of the female is sufficient for the production of as many as 10 groups of fertile eggs, even though five months or more passed in hibernation intervene between mating and the first egg deposition in the spring. (See Table 1.) Gravid females may thus enter hibernation and without further intervention of the male deposit fertile eggs in the spring. The beetles always feed on foliage in the spring before oviposition.

The young larvæ hatch from the eggs after from 5 to 14 days, depending upon temperature conditions, the average incubation period at Birmingham, Ala., during June, July, and August being 6 days. Hatching of all eggs in a group usually occurs within 24 hours. The newly hatched larvæ leave the eggshells and cling to the tips of the eggs, completely covering the shells. They begin to feed soon after leaving the eggs, many of them reaching the leaf and feeding while clinging to the eggshells about the edge of the group. A very thin layer of epidermis is eaten. After a day or so the larvæ begin to scatter and feed more heavily, devouring thicker portions of the leaf. By the time of the first molt they have scattered over several leaves. As they grow older they feed heavily and more rapidly and scatter over the plant or adjacent plants. In the third and fourth larval instars the most serious damage is done to the crop.

The larvæ (Pl. IV, *C*) remain on the plant on which they have hatched, or on adjacent plants. While capable of crawling a considerable distance under adverse conditions, as much as 24 feet in 20 minutes, migrations do not usually occur except prior to pupation when sufficient protection is not at hand.

The larva's method of feeding is characteristic of the species. (Pl. V, *A*, *B*.) It consumes a narrow band of the leaf and usually leaves the upper epidermis intact. It then moves and consumes another strip, and so on until several such parallel strips have been

devoured. The result is a network of narrow bands of leaf tissue covered by the thin upper epidermis. The feeding habits of the beetle are quite similar to those of the larva in many cases, but usually the leaves are more ragged in appearance.

The 12-spotted cucumber beetle (*Diabrotica 12-punctata* Oliv.) feeds very similarly in many cases, as do also certain small caterpillars.

In territory where the bean beetle is not numerous, specimens of suspected insects should be taken for identification before the presence of the bean beetle is reported.

After the larva has molted three times the fourth larval instar or stage appears. Feeding by the larva in this stage is very destructive, a single larva being able to destroy a large bean leaf in one day. After feeding for from 4 to 6 days in moderately warm weather the larva attaches itself by means of an abdominal pad at the posterior end and remains quiescent for about 2 days. A fourth larval molt then occurs and the pupa stage is assumed. The larval skin, which is white in color, remains attached to the yellow-colored pupa (Pl. II, *B;* Pl. III; Pl. IV, *D*), covering the posterior abdominal segments and holding the pupa to the leaf or other object. Late in the fall the pupal skin is often black in streaks and sometimes completely black. Under conditions of severe infestation, pupæ occur on various plants and objects near destroyed plants. Egg masses are also deposited on such plants as mustard, cocklebur, and certain weeds, on which the hatching larvæ would starve.

The adult or beetle emerges from the pupa in from 6 to 8 days. Immediately on emergence it is light lemon-colored and very soft. In a few hours the spots on the wing covers appear. The wings are protruded backward from under the elytra or wing covers, extending a distance almost the length of the body. At the end of 24 hours the adult becomes fully developed and quite hard, but the color is light lemon, with black spots, and dark mouth parts, undersurfaces, and appendages. With age the color becomes darker, approaching copper color to brown in overwintered specimens.

Newly emerged adults (Pl. IV, *E*) usually remain on the bean plant and feed before taking flight. Food is not essential, however, and in cases where fields are destroyed newly emerged beetles fly away in search of food.

The fecundity of the insect under favorable circumstances is remarkable. During the summer of 1921 many fields of beans about Birmingham, Ala., were so heavily infested that the general appearance of the crop resembled the effect of a severe drought. Scattered over the remains of the plants, the ground, weeds, and any object were thousands of pupæ and larvæ, so numerous as to give a yellow tone to the field. Larvæ and beetles feed on pods and stems under such conditions.

The total life period from egg to adult covers from 25 days during the heat of summer to 58 days in early spring, the usual minimum being 27 days during summer, and the usual maximum during the spring and fall being about 44 days. From 6 to 29 days additional are required between emergence of the female from the pupa and egg deposition. The average preoviposition period for 32 females in two different seasons was 11.5 days. Table 3 gives a brief summary of the life history at Birmingham, Ala., for the years 1921 and 1922.

TABLE 3.—*Summary of life history of the Mexican bean beetle at Birmingham, Ala., 1921 and 1922.*

[Average days of development.]

1921: 2,019 EGG-TO-ADULT RECORDS.

Generation.	Incubation period.	First instar.	Second instar.	Third instar.	Fourth instar.	Pupation period.	Developmental period.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
First generation	10	5	6	4	8	6	39
Second generation	6	4	3	3	6	6	28
Third generation	6	4	3	3	6	6	28
Fourth generation	6	3	3	4	8	7	31
1922: 1,407 EGG-TO-ADULT RECORDS.							
First generation	8	5	4	5	8	6	36
Second generation	6	4	4	4	8	7	33
Third generation	6	4	4	4	8	7	33
Fourth generation	7	5	5	7	10	12	46

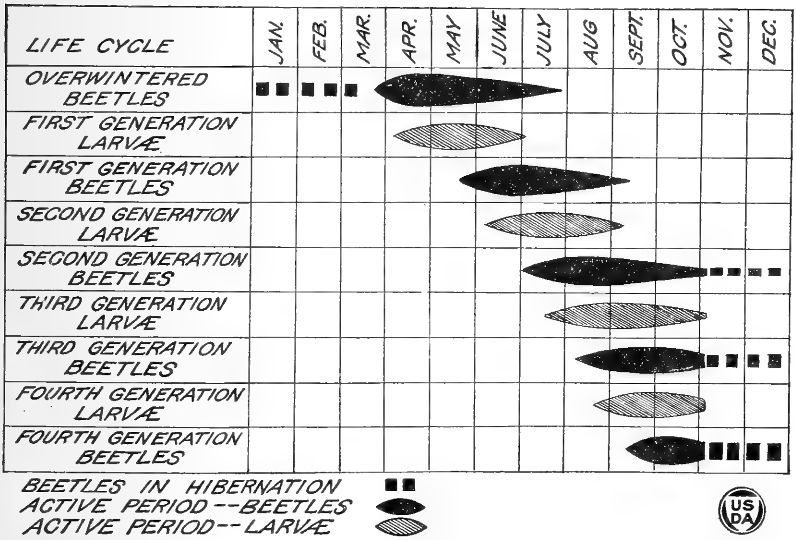


FIG. 6.—Life history of the Mexican bean beetle in an open-air insectary and field cages at Birmingham, Ala., during 1921. Based on 2,393 egg-to-adult rearings.

SEASONAL LIFE HISTORY.

The discussions in this bulletin are based on observations covering only a two-year period in a restricted locality, which is too short a time to draw conclusions on many phases, especially since this study deals with an insect in a new habitat with a constantly increasing distribution.

A large series of life-history experiments were performed during the two seasons, 1921 and 1922, and these have been condensed into charts. (Figs. 6, 7.) Figure 6 gives the results of 2,393 egg-to-adult rearings, obtained during the year 1921, chiefly by J. R. Douglass. Figure 7 gives the results of 1,590 egg-to-adult rearings, obtained

during 1922 by L. W. Brannon. During 1922 many egg masses obtained were not reared. All the original beetles were taken from hibernation. Cages were placed in the field as well as in the insectary, and identical results were obtained.

These charts show overlapping of generations, due to the prolonged life of the adults, especially the overwintering generation. They also show that while the insect can and does produce a maximum of four generations, a minimum of two is required to maintain the species except in rare instances. Two generations and a partial third are the rule.

All stages of the insect occur in the field from late April or early May until late October or early November about Birmingham, Ala. At Thomasville, Ga., all stages have been observed in the field from April until late November or even December. A maximum of four

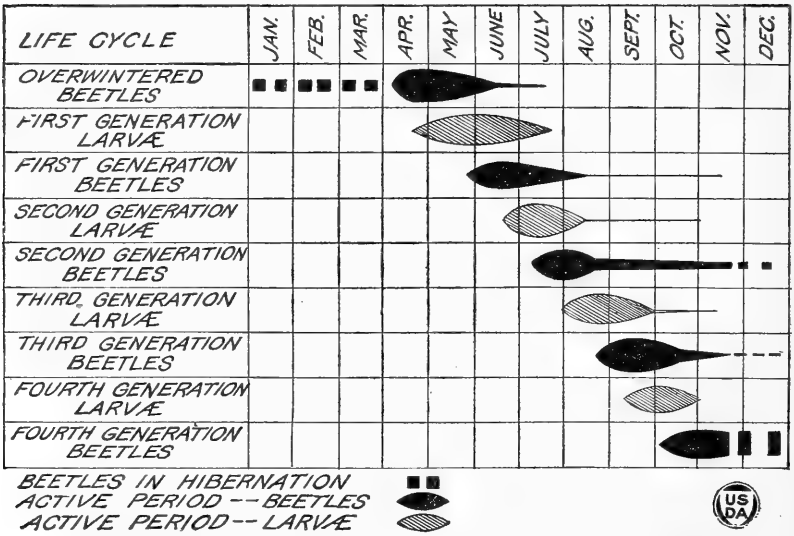


FIG. 7.—Life history of the Mexican bean beetle in an open-air insectary and field cages at Birmingham, Ala., during 1922. Based on 1,590 egg-to-adult rearings.

generations occurred there, although the duration of bean plantings would permit a maximum of six generations. Two generations and a partial third are the rule, as in northern Alabama.

In the field the severest damage is done by the first and second generations.

Figure 8 represents the seasonal life history. This chart was prepared from the life-history studies and records of infestation made in field control experiments during 1921 and 1922. The width of the bands indicates the relative abundance of the beetles and larvæ, calculated from injury to beans. The early records of 1921 are probably unusual, and the heavy late infestations of that year were not repeated in 1922. The heaviest infestation occurs in July and early August, when the greatest number of larvæ are present. In 1921 the period of heavy infestation extended over a period of about three months from late June to the middle of September, but in 1922 this period was of shorter duration—from late June to early August.

In the Southeast the beetles begin to leave their winter quarters in the spring as early as late March and early April, or at about the time when early garden beans are coming up. At Birmingham, Ala., this date was March 22 in 1921, and April 6 in 1922. At Chattanooga, Tenn., it was early in May in 1922. At Thomasville, Ga., the first beetles emerged in the field March 27, 1922. One individual of a colony of beetles, marked black, November 18, 1921 (Group 2, Table 6), was collected in a bean field April 22, 1922, three-fourths of a mile from the place where it had spent the winter. The beetle is thus able

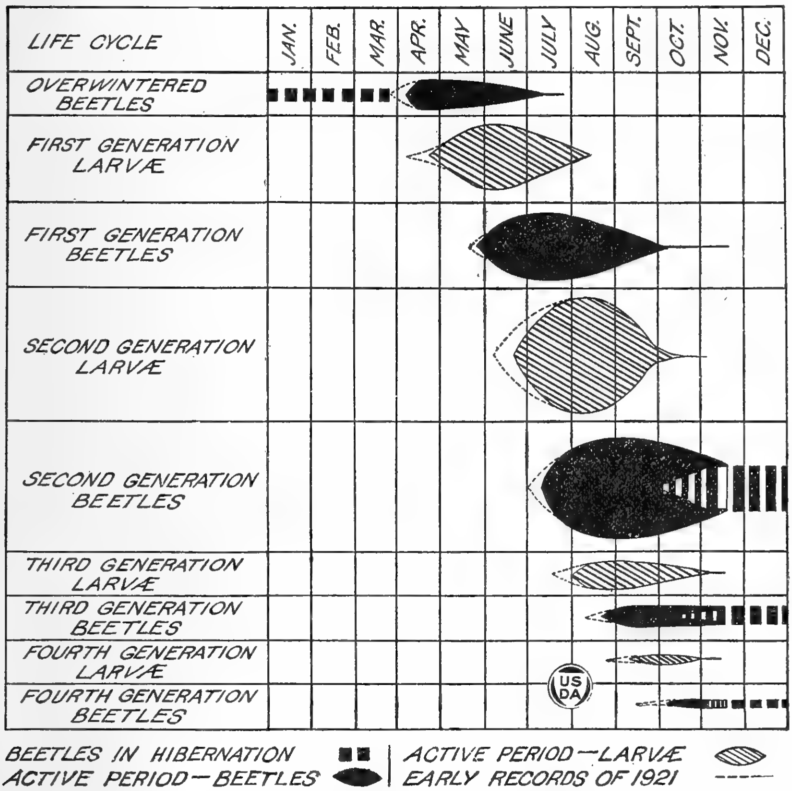


FIG. 8.—Seasonal life history of the Mexican bean beetle: Composite chart prepared from insectary records and field observations during 1921 and 1922 near Birmingham, Ala. (eggs and pupæ not shown). Width of bands shows relative abundance of beetles and larvæ in the field. The insect is most abundant in July.

to make extensive flights at this time of the year. In New Mexico, J. E. Graf found beetles hibernating $7\frac{1}{2}$ miles from the nearest bean field, and still farther from the most likely source.

The spring migration lasts until early June, covering a period of about two months. The beetle flies considerably all during the summer from field to field and travels great distances.

During August, 1921, and late July, 1922, the beetles became restless and were often on the wing. During this period beetles a week or more old fed less than earlier in the season. It is believed that the greatest distribution occurs during the late summer and early fall, but the spring migration is also undoubtedly of great importance.

At least as early as the first week in October the beetles begin to fly to woodlands and enter hibernation. The majority have left the fields by the time the daily mean temperatures reach 55° to 60° F., but a few remain until heavy frosts occur.

Fewer eggs are laid after the middle of August. Larvæ are correspondingly scarce, but all stages are present until killing frosts occur.

Life for long periods without food, as shown by starvation tests, indicates that the species is remarkably prepared for adverse conditions when host plants may be unavailable. One adult lived 102 days without food in the presence of moisture. In general they

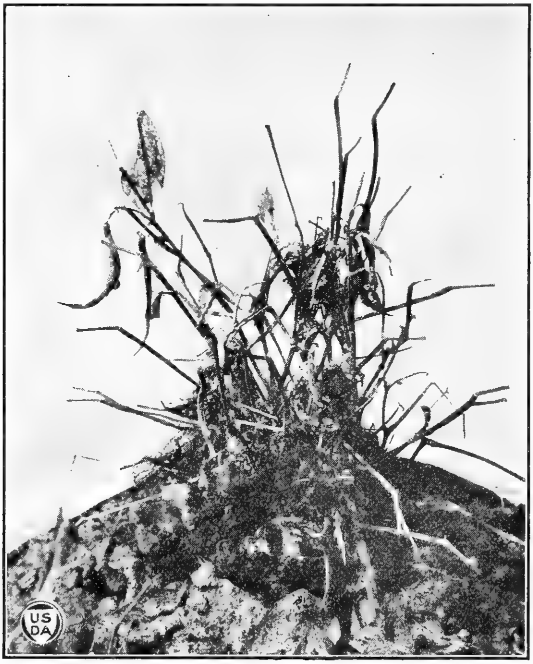


FIG. 9.—A typical infested bean plant photographed in the field shown in Plate VI, *B*.

succumb to starvation after 5 to 15 days, but a few live considerably longer. After starving for 68 days, 19 beetles out of 50 survived and entered hibernation November 22, 1922. An adult with food lived 121 days. The average life of 34 pairs used in experiments was 58 days, the females averaging 50 days and the males 68.

FOOD PLANTS.

The Mexican bean beetle is primarily a bean pest (Pl. VI, *A*, *B;* text fig. 9), attacking by preference the common beans, including bush and pole varieties of snap beans, pinto, navy, and Lima beans, and tepary beans, all of the genus Phaseolus. It can subsist, however, on a number of other plants, and in many instances has severely damaged cowpeas and soy beans. About Birmingham, Ala., in 1921, and about Chattanooga, Tenn., in 1922, some fields of cowpeas were

destroyed, and serious injury in some instances was done to soy beans. The following list of food plants comprises those observed to date, in the order of their preference, on which both larvæ and beetles can subsist, as observed in the field.

FOOD PLANTS OF THE MEXICAN BEAN BEETLE.

Tepary bean (*Phaseolus acutifolius*).
Garden bean (*Phaseolus vulgaris*); including navy bean, pinto bean, kidney bean, pole bean, etc.
Lima bean (*Phaseolus lunatus*).
Beggarweed (*Meibomia tortuosa, M. canescens, M. viridiflora*).
Hyacinth bean (*Dolichos lablab*).
Cowpea and black-eyed pea (*Vigna sinensis*).
Soy bean (*Glycine hispida*).
Adsuki bean (*Phaseolus angularis*).
Alfalfa (*Medicago sativa*).
Sweet clover (*Melilotus alba*).

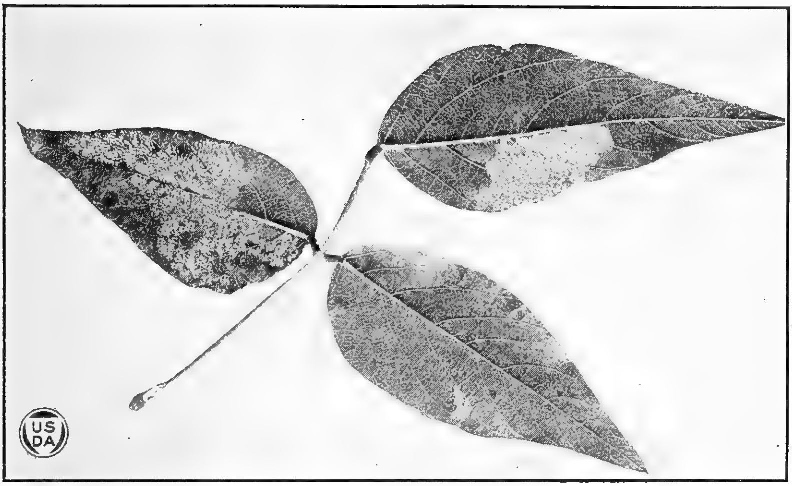


FIG. 10.—Voluntary larval feeding on beggarweed (*Meibomia* sp.).

There is a very great difference in choice between some of these food plants. In some cases of light infestations, cowpeas and soy beans may be uninjured. Also, early in the season, beetles and larvæ may starve in confinement on these plants, while later in the year they will reproduce on them and may cause serious injury in the field in cases of heavy infestations.

In the late summer and fall, when bush bean foliage is scarce but when pole Lima beans are large and green, the beetles are attracted to the latter. This crop is examined closely in fall scouting work in new territory. The list given is based on field observations.

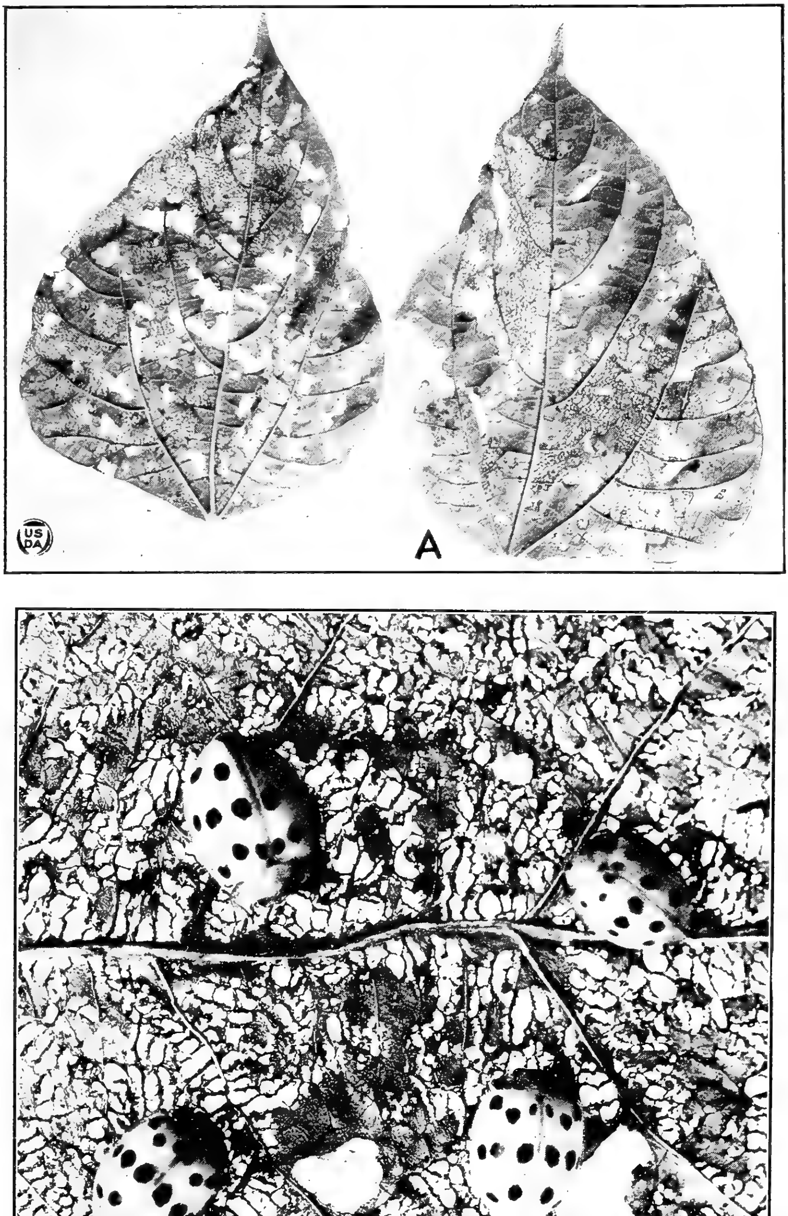
In the insectary the insect has been reared from egg to adult on many varieties of bean—on *Meibomia canescens* (fig. 10), cowpea (Pl. VII, *A*, *B*), hyacinth bean, soy bean (Pl. VIII, *B*), and adsuki bean—and to the pupa stage on alfalfa, when ants destroyed the pupæ. The likelihood of the insect severely damaging plantings of the adsuki bean, sweet clover, or alfalfa (Pl IX, *A*) is very remote. Beetles and larvæ in confinement often starve in the presence of the last two plants. When extremely numerous the beetles have been

observed to feed voluntarily on many plants, especially when their favorite food has been destroyed or has become scarce. Among these plants are the following: Velvet bean, kudzu, crimson clover, white clover (Pl. IX, *B*), corn, grasses, okra (Pl. VIII, *A*), eggplant, potato, squash, mung bean (*Phaseolus aureus*), and weeds. None of these plants has ever been severely damaged. Adults have also been taken feeding on *Galactia volubilis* and *Lespedeza virginica*. In the fall volunteer feeding on kudzu is not uncommon, while trials earlier in the year to breed the insect on this host have been fruitless. Feeding on mung bean (*Phaseolus aureus*) is very rare, and only one instance of feeding on wild morning-glory (*Ipomoea* sp.) has been observed, under unusual conditions. The insect does not normally feed on sweet potato or peanut. Information relative to the preference of the beetle for snap beans, both pole and bush, compared with Lima beans, cowpeas, and soy beans, may be gained from the reports on field scouting, most of which was done in sections where infestation was light. These reports show a decided preference of the beetle for the garden bean over the Lima bean, that the cowpea is far removed from either of these, and that the latter is preferred to soy bean. In south Georgia beggarweed (*Meibomia tortuosa*) is preferred to cowpea, this plant being infested with all stages of the insect when cowpea is scarcely infested.

The problem of food plants of the Mexican bean beetle is not the same in the Southeast as in the West and Southwest. Not only does the problem concern the grower of susceptible crops, but it has an important bearing on the policy to be followed regarding quarantine and extermination policies. The fact that a number of new food plants came under observation immediately after investigation of the problem is evidently explained by the fact that the insect acts differently under new climatic conditions. Obviously, also, some apparently new habits may be of old standing.

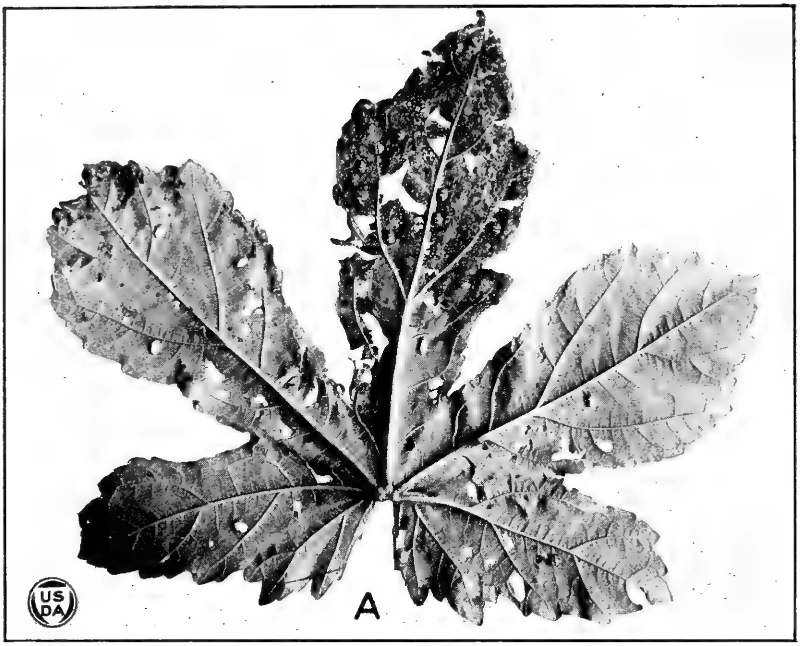
Soon after the avidity of the beetle for beggarweed or beggartick (*Meibomia tortuosa*) in southern Georgia was reported by Luther Brown, the same facts were independently discovered in Mexico by Prof. H. F. Wickham, while employed by the Bureau of Entomology. Similar observations were made in northern Alabama by J. R. Douglass and the writers and subsequently in Mexico in 1922 by E. G. Smyth. It is therefore probable that Meibomia has been a host plant for many years. In 1920, when the bean beetle was first reported in northern Alabama, cowpea and soy bean were observed as food plants. Adults were first observed feeding on soy bean, in Colorado, by A. E. Mallory, Bureau of Entomology, in 1919. The greater variety and accessibility of leguminous food plants in the southeastern part of the United States, together with the abnormal abundance of the insect, has probably been the chief cause of changes of habit and new observations of old habits. In trucking sections in the Southeast cowpeas are often raised as a truck crop for human consumption in the green stage. In many such instances severe damage has been done to this crop. In a number of cases marked injury to fields of cowpea of considerable size has occurred, but always in a section where the infestation on garden beans has been extremely heavy.

A decided preference is shown by the Mexican bean beetle for "pinto" and tepary beans. In 1921 pinto, or Rosello spotted, beans



WORK OF THE MEXICAN BEAN BEETLE ON COWPEA

A, Voluntary larval and adult feeding on cowpea; *B*, beetles feeding on cowpea leaf



WORK OF THE MEXICAN BEAN BEETLE ON OKRA AND SOYBEAN

A, Okra leaf, taken in field, showing beetles and larvæ feeding; *B*, soybeans injured by feeding

from Colorado were planted with a legume collection on the experimental plats. Careful counts showed that more than twice as many adults were present on the pinto beans, and they were destroyed sooner than a collection of six of the most popular varieties of garden bush beans. In 1922 tepary beans were decidedly preferred to 11 varieties of the commonest pole and bush beans, although the leaves were small and the insect was exposed to the sun. These facts support the statement that the bean beetle was introduced from the western part of the United States, for these varieties are grown extensively there.

HIBERNATION.

Knowledge of the hibernation habits of the Mexican bean beetle previous to the winter of 1921–22 was based on the collection of very few specimens during the fall and winter. The greater portion of the life cycle of many important injurious insects, especially in the Temperate Zones, is passed in a dormant state during winter, but in many instances little is known about this stage. Attack on insects during this period has been found successful in notable cases, such as the clean-up practices recommended in some localities against the chinch bug, *Blissus leucopterus* Say, and the planting of wheat to take advantage of the seasonal life history and hibernation habits of the Hessian fly. Other outstanding examples might be mentioned.

The adult of the bean beetle is the only stage which survives the winter. In 1921 emergence from hibernation was first noted March 22, when four adults were collected on early beans. An egg mass was also collected, indicating that emergence had occurred a few days before. In field observations emergence and spring migration lasted until the middle of May, the greatest number having emerged by late April and early May.

Restlessness of adults in the field was noted in August, 1921, and from that time until late October migrations occurred. Beetles were exceedingly numerous until that time, but had almost disappeared from the field by November 4, when a heavy frost occurred. A few specimens were observed up to November 25, 1921, on parts of bean foliage which had not been killed by frost.

Adults of the Mexican bean beetle have been found hibernating under various conditions. They have been collected in old stumps near a garden, in cracks of old fence posts, in débris about an old fence, in stone piles near a garden, under leaves and plant remains in the garden, under a woodpile, and in well-drained woodlands near bean fields.

Experience gained in California in investigating the hibernation of beneficial coccinellids led J. E. Graf to believe that the Mexican bean beetle, which is a coccinellid, hibernates similarly. Therefore, a large area surrounding the Birmingham trucking district in the East Lake section was carefully searched for the beetle during the winter of 1921–22. The results are given in Table 4.[4]

This area comprised approximately 12 square miles and the same territory was searched again in the winter of 1922–23. These results are shown in Table 5.

[4] M. P. Foshee, D. M. Dowdell, Jr., and others assisted in this work.

TABLE 4.—*Hibernation of the Mexican bean beetle, Birmingham, Ala., winter of 1921–22.*

Hill No.	Number of searches.	Number of square feet covered.	Number of colonies found.	Number of beetles found in colonies.	Number of single beetles found.	Total number of beetles found.
1	10	515	0	0	3	3
2	20	1,023	3	649	154	803
3	25	1,686	0	0	63	63
4	3	344	1	30	32	62
5	4	374	0	0	3	3
6	3	196	0	0	1	1
7	17	420	0	0	0	0
8	5	1,896	0	0	43	43
9	42	7,989	4	233	287	520
10	7	690	0	0	0	0
11	7	1,075	0	0	1	1
12	12	629	0	0	26	26
13	27	2,287	0	0	34	34
14	12	882	0	0	0	0
15	5	500	0	0	38	38
16	19	644	0	0	2	2
18	6	488	0	0	0	0
19	8	991	0	0	0	0
20	9	1,113	0	0	0	0
21	10	1,750	0	0	267	267
22	6	968	0	0	2	2
23	11	936	0	0	3	3
24	11	1,152	0	0	0	0
25	6	376	4	380	2	382
26	8	339	0	0	0	0
27	5	480	0	0	0	0
28	7	360	0	0	4	4
29	5	603	0	0	1	1
30	5	35	0	0	0	0
31	13	1,433	0	0	11	11
32	13	476	0	0	0	0
38	13	478	0	0	0	0
39	13	390	0	0	12	12
40	12	364	0	0	0	0
41	9	361	0	0	0	0
42	7	291	0	0	0	0
43	7	580	0	0	0	0
44	7	559	0	0	0	0
45, Watt's farm	62	5,086	0	0	9	9
Total	471	40,759	12	1,292	998	2,290

TABLE 5.—*Hibernation of the Mexican bean beetle, Birmingham, Ala., winter of 1922–23.*

Hill No.	Number of searches.	Number of square feet covered.	Number of colonies found.	Number of beetles found in colonies.	Number of single beetles found.	Total number of beetles found.
1	13	554	0	0	1	1
2	20	1,276	0	0	1	1
3	59	4,933	0	0	10	10
4	46	3,449	0	0	17	17
5	15	522	0	0	0	0
6	45	4,334	0	0	0	0
7	15	557	0	0	0	0
8	27	1,958	0	0	0	0
9	77	7,484	0	0	14	14
11	21	1,042	0	0	0	0
12	38	4,168	3	167	145	312
13	15	829	0	0	0	0
15	27	2,609	0	0	3	3
16	7	299	0	0	0	0
19	23	1,167	0	0	2	2
21	36	3,139	0	0	31	31
22	39	3,660	0	0	0	0
23	37	1,998	0	0	0	0
25	39	1,580	0	0	54	54
26	23	1,082	0	0	0	0
28	13	484	0	0	0	0
32	30	1,526	0	0	4	4
45	56	5,244	0	0	0	0
Total	721	53,894	3	167	282	449

Approximately 12 square miles were included in hibernation scouting. The greatest distance beetles were found from a bean planting is one-half mile. The majority of the beetles found were within one-eighth to one-fourth mile from the nearest bean plantings.

The largest numbers of hibernating beetles have been found in woodlands where the land is rolling. In all cases where living beetles were taken, the material sheltering them was moist and was protected from driving winds. As this material dried out, during warm weather, the beetles moved about and went farther into the material where moisture was present, or migrated to more favorable quarters.

In sections where the infestation is extremely heavy there is a tendency toward hibernating gregariously. About Birmingham, Ala., in the winter of 1921–22, 56 per cent of the 2,290 beetles observed were found in colonies. The following winter, 1922–23, only 14.8 per cent as many beetles were found per unit of area as during the previous winter. This was probably due to the lighter infestation during 1922.

The largest colony observed contained 329 beetles on December 15, 1921, and the majority of beetles occurred in a space 18 inches square. The colony shown in Plate X, *A*, *B*, contained 149 beetles, more than 50 of which were in a space less than 1 foot square, about 1 inch below the surface. This colony was under pine needles and oak leaves which had accumulated under a pine branch on the ground.

During cold weather in January adults withstood submersion in water for two days with no mortality. Fifty per cent of the beetles survived after submersion for four days, and one beetle was living after six days. In small hibernation cages which were not sufficiently moist all beetles succumbed.

Males and females occur in approximately equal proportions.

The few beetles which remain in the bean fields during winter are undoubtedly a factor in the spring infestation, but the large majority of adults migrate from the fields to wooded hills. The proper moisture conditions for successful survival of the winter appear to be an important factor in determining the location chosen. These conditions are only constant under branches and leaves in the shade, or in deep piles of material. The preferred material in the Southeast is a mixture of pine needles and oak leaves. (Pl. X.) The beetles are found distributed through the material at a depth of an inch or more, depending on the moisture conditions. Adults are occasionally found with colonies of the beneficial ladybird, *Megilla maculata* DeG.

October 3, 1922, three beetles were observed in hibernation in woodlands when the shade temperature was 82° F. Three days later 25 beetles were found in the same place.

During the mild winters of the Southeastern States the adults are not entirely inactive. On warm days they move about, and in the course of the winter the majority change location. Some of the colonies of beetles found in woodlands were watched throughout the winter. Each beetle was marked with a waterproof mark. Brief records of the observations are given in Tables 6 and 7.

TABLE 6.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1921–22.*

GROUP 1.

[149 beetles in original colony, marked red, November 22, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Nov. 30		24		
Dec. 9		47		
Dec. 15	Destroyed by intruders.			

GROUP 2.

[299 beetles in original colony, marked black, November 18, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Nov. 30		30		
Dec. 9	200	103		
Dec. 15	161	168	6	2
1922.				
Jan. 3 [1]	156	170	6	9
Jan. 17	156	166	10	14
Jan. 22	116	141	11	10
Feb. 17	93	115	5	29
Feb. 24	85	110	95	9
Mar. 8	65	85	7	7
Mar. 18	54	54	3	6
Mar. 29	40	38	4	2
Apr. 13	25	18	1	0
Apr. 26	10	8	0	0
May 10	0	0	0	0

GROUP 3.

[80 beetles in original colony, marked purple, December 10, 1921.]

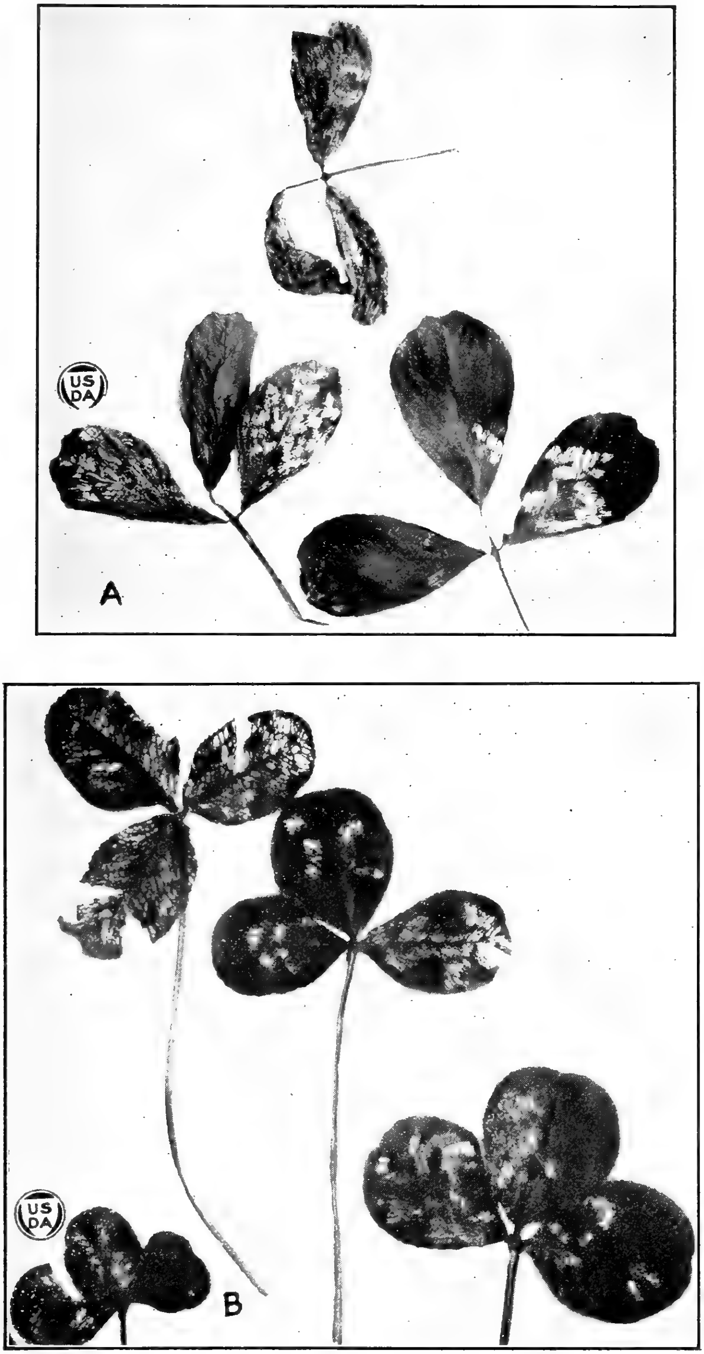
Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Dec. 15	68	8		
1922.				
Jan. 3	59	11	3	0
Jan. 17	47	9	1	1
Jan. 31	57	9	0	1
Feb. 18	51	9	0	1
Feb. 23	41	8	1	1
Mar. 6	37	6	1	1
Mar. 18	30	6	0	1
Mar. 27	24	4	1	0
Jan. 6	Beetles noted with snow on ground; more closely grouped.			
Feb. 23	Temperature moderating and beetles scattered generally through covering.			
Apr. 13	16	1	0	0
Apr. 26	5	1	0	0
May 10	0	0	0	0

GROUP 4.

[65 beetles in original colony, marked white on left wing cover, December 10, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Dec. 15	43	12		
1922.				
Jan. 3	40	10	1	1
Jan. 17	35	16	0	0
Jan. 31	29	8	0	2
Feb. 18	26	11	0	0
Feb. 23	22	13	0	0
Mar. 6	20	5	0	7
Mar. 18	20	3	1	0
Mar. 27	13	5	0	0
Apr. 13	9	4	0	0
Apr. 26	3	1	1	0
May 10	0	1	0	0

[1] Majority of beetles found in space 18 inches square.



WORK OF MEXICAN BEAN BEETLE ON ALFALFA AND CLOVER

A, Voluntary feeding on alfalfa; *B*, voluntary feeding on white clover

HIBERNATION OF THE MEXICAN BEAN BEETLE

A, Woods in which Mexican bean beetle was found hibernating in colonies; *B*, Mexican bean beetles hibernating gregariously in woods under pine straw and oak leaves. *B* was taken after pine branch shown in foreground in *A* was removed

TABLE 6.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1921–22*—Continued.

GROUP 5.

[72 beetles in original colony, marked green on right wing cover, December 13, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Dec. 15	70	0	......	......
1922.				
Jan. 3	Destroyed by intruders.		......	......

GROUP 6.

[103 beetles in original colony, marked red (eosin) on right wing cover, December 13, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles, painted.	Dead beetles, unpainted.
1921.				
Dec. 15	96	0	......	......
1922.				
Jan. 3	85	4	3	0
Jan. 17	69	1	4	0
Jan. 22	68	2	4	0
Feb. 18	65	0	0	0
Feb. 23	64	0	0	0
Mar. 7	57	3	0	0
Mar. 18	51	1	0	0
Mar. 27	40	3	1	0
Apr. 13	18	1	0	1
Apr. 26	3	1	0	1
May 10	0	0	0	0

TABLE 7.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1922–23 (through Feb. 9, 1923).*

GROUP 7.

[25 beetles in original colony, in space 3 feet by 5 feet, Oct. 3, 1922.]

Date.	Number of beetles present.
1922.	
Nov. 6	8
Nov. 8	3
Nov. 10	4
Nov. 12	4
Nov. 21	4

GROUP 8.

[61 beetles in original colony, in space 4 feet square, Dec. 4, 1922.]

Date.	Number of beetles present.
1922.	
Dec. 14	16
Dec. 20	0

TABLE 7.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1922–23 (through Feb. 9, 1923)*—Continued.

GROUP 9.

[81 beetles in original colony, in space 5 feet by 10 feet, marked black, Dec. 20, 1922.

Date.	Number of beetles painted.	Number of beetles unpainted.	Remarks.
1922.			
Dec. 20	81		
Dec. 30	31	15	Slightly active.
1923.			
Jan. 5	30	19	Inactive.
Jan. 12	29	19	Slightly active.
Jan. 31	21	12	Active.
Feb. 9	22	21	Inactive.

The mortality in the woods during hibernation is not as great as might be expected. Remains of beetles have been found which indicate the work of carabid beetles or other predacious enemies. The high mortality in Group 2 (Table 6) is unusual.

Records of hibernation were also obtained from cages. At Birmingham, Ala., 17,800 beetles were placed in cage 1, and were given their choice of materials which had been found by Dr. W. E. Hinds to be satisfactory the previous winter. The materials used were wood, sticks, cornstalks, and bean vine débris, a fourth of the cage being left bare. The cage was placed under a small tree which shaded it about half the day. Beetles numbering 18,050 were placed in cage 2, similar to cage 1, and with similar materials, but in a location a mile and a half away, where the cage was not shaded. These cages were placed at an altitude of about 600 feet above sea level, in latitude 33° 31′ N.

Observations were made of cage 2 at intervals during the winter. As noted in the field observations, many of the beetles moved about on warm days throughout the winter.

Air temperatures were taken in the shade as observations were made. No beetles were observed to be out of the hibernating material below a temperature of 50° F., and very few were out at temperatures below 60° F. At 60° F. and above, up to 70° F., from 30 to 200 beetles would crawl about the top of the material and on the sides of the cage, depending on the amount of sunlight. Above 70° F., the beetles became more active, and March 30, 1922, at 75° F., 724 beetles were out and active. Early spring migration and issuance from hibernation probably took place under natural conditions about that date, although the first adult was not taken on beans until April 6. After March 20 the beetles in the cages were active at temperatures below 60° F. on some days. April 1, when the temperature was 45° F., 124 beetles were out. Almost all the beetles hibernated under the pile of wood and sticks, several inches below the surface, where the material was constantly moist. A few beetles hibernated in the bean vine débris.

In the spring, about the time appearance on the earliest garden beans was expected, as indicated by observations of beetles under natural conditions, beetles were removed as fast as they crawled on the sides of the cage. The emergence in the cages is given in Table

8. It will be noted that the survival of beetles was slightly less than 15 per cent in each cage.

The total period of emergence was about two months—from April 5 to June 6. The maximum emergence occurred between April 19 and May 6 in the two cages, which is more than a week later than the previous year. The majority of the beetles observed throughout the winter in nature (Table 6) had left hibernation by April 26, and all except one had issued by May 10.

TABLE 8.—*Hibernation at Birmingham, Ala., winter of 1921–22.*

CAGE 1.

Beetles collected.		Beetles removed.	
Date.	Number.	Date.	Number.
Sept. 21	500	Apr. 5	100
Sept. 22	800	Apr. 12	85
Sept. 23	6,000	Apr. 22	220
Sept. 24	5,200	Apr. 27	180
Sept. 29	600	May 3	300
Sept. 30	4,700	May 5	753
		May 6	301
		May 8	267
		May 12	102
		May 19	203
		June 2	73
		June 6	16
Total	17,800	Total	2,600
		Percentage survival	14.61

CAGE 2.

Beetles collected.		Beetles removed.	
Date.	Number.	Date.	Number.
Oct. 1	4,700	Apr. 4	100
Oct. 2	1,350	Apr. 5	314
Oct. 3	3,000	Apr. 12	186
Oct. 5	3,200	Apr. 17	1,036
Oct. 7	1,800	Apr. 19	213
Oct. 8	4,000	May 4	453
		May 8	231
		May 20	105
Total	18,050	Total	2,638
		Percentage survival	14.61

HIBERNATION AT CHATTANOOGA, TENN.

The Mexican bean beetle reached Chattanooga, Tenn., early in 1921, and reproduced rapidly that year. It had not become abundant, however, by fall. In October, 18,000 beetles, collected at Birmingham, Ala., were placed in hibernation on Lookout Mountain in Tennessee, in a cage and with materials for protection similar to those used at Birmingham, Ala. The altitude of this mountain is more than 2,100 feet above sea level, and the latitude is 35° 21′ N. Beetles were removed when the locality was visited and the results are given in Table 9. The survival in this cage was lower than in the others, probably because the beetles were not removed regularly. No attempt was made to estimate the mortality due to starvation in the spring, but it is believed that a higher percentage of survival would have been obtained if the cage had been observed daily. Of the adults placed in this cage, 9.7 per cent survived the winter. The

maximum emergence, estimated from observations, probably occurred from May 10 to May 27, which is three weeks later than at Birmingham, Ala., where cages were placed at 600 feet above sea level, at 33° 31′ N. latitude. The insect at the latitude and altitude of Lookout Mountain remains in hibernation from 7½ to 8 months.

TABLE 9.—*Data on hibernation cage at Chattanooga, Tenn., on Lookout Mountain, winter of 1921–22.*

Beetles collected at Birmingham, Ala.		Beetles emerged.	
Date.	Number.	Date.	Number.
Oct. 5	6,000	Apr. 26	37
Oct. 6	12,000	May 16	465
		May 18	585
		May 27	629
		June 10	24
Total	18,000	Total	1,740
Beetles transported to Chattanooga and placed in cage Oct. 11.		Next observation was June 29, when there were no living beetles in the cage.	
		Percentage survival	9.7

HIBERNATION AT THOMASVILLE, GA.

The isolated infestation at Thomasville, Ga., offers an interesting comparison of the habits of the Mexican bean beetle at a low altitude (about 300 feet above sea level) and more southern latitude (30° 54′ N.) with those at the higher altitudes and more northern latitudes of Birmingham, Ala., and Lookout Mountain, Tenn.

Hibernating habits under natural conditions at Thomasville, Ga., during the winter of 1921–22 were very similar to those about Birmingham, Ala. Because of the lighter infestation and the relatively smaller acreage of bean plantings, adults were not so numerous. An area of several square miles surrounding the city was included in the study of hibernation. A total area of 4,823 square feet, representing 718 searches, was examined carefully. Of 152 adults observed in hibernation, 69 per cent were found in a colony comprising 105 beetles. These were found at the base of a large oak, growing in contact with a large gum tree. The beetles were distributed from 1 to 3 inches below the surface in oak and gum leaves. Close by was a garden which had contained pole Lima beans which had been destroyed by the beetle the previous summer.

In searching for hibernating bean beetles many adults of the related squash beetle[5] were also observed in hibernation, often under identical conditions, side by side, under leaves on the ground. The well-known habit of the squash beetle of hibernating in crevices in the bark of trees has not been observed in the case of the bean beetle.

A hibernation cage like those mentioned above was used at Thomasville. (See Table 10.) In 1921 the majority of the beetles left the fields late in October, but a few were present as late as December. The first issuance from hibernation observed in the field was March 29, 1922, but, as noted in Table 10, emergence began February 28 in the cage and continued until June 3. The survival was 30

[5] *Epilachna borealis* Fab.

per cent. This high rate, however, may be partially due to the fact that the dormant period of a portion of the beetles is reduced to less than four months.

TABLE 10.—*Data on hibernation cage at Thomasville, Ga., winter of 1921–22.*

Beetles collected.		Beetles issued.	
Date.	Number.	Date.	Number.
1921.		1922.	
Sept. 28–30	1,690	Feb. 28	79
Oct. 1–6	1,625	Mar. 1–11	153
Oct. 8–15	708	Mar. 13–18	97
Oct. 17–25	259	Mar. 27–31	93
Oct. 26–31	234	Apr. 1	116
Nov. 1–10	342	Apr. 2	30
Nov. 12–18	253	Apr. 3–6	339
Nov. 25–30	190	Apr. 7–12	154
Dec. 1–12	157	Apr. 13–19	261
		Apr. 21–28	170
1922.		May 1–6	90
Jan. 21	24	May 8–13	43
Jan. 31	12	May 17	27
		May 22	6
		May 26	2
		May 29	6
		June 3	1
Total	5,494	Total	1,667
		Percentage survival	30.34

HIBERNATION CAGE SUMMARY.

Cage.	Number of beetles placed in cage.	Number of beetles emerged.	Per cent survived.
Thomasville, Ga	5,494	1,667	30.3
Birmingham, Ala., Cage 1	17,800	2,600	14.6
Birmingham, Ala., Cage 2	18,050	2,638	14.6
Chattanooga, Tenn. (Lookout Mountain)	18,000	1,740	9.7

The maximum emergence in the cage occurred between April 1 and April 6, when 485 emerged, which is 18 to 31 days earlier than at Birmingham, Ala., and 39 to 51 days earlier than at Chattanooga, Tenn.

In the mild climate of southern Georgia the time between the earliest entrance into hibernation and the latest emergence covers about 7 months, a relatively long period. The time from the entrance of the last beetle into hibernation until the first emergence is only about 3½ months. The majority of the beetles remain in hibernation about 5 months. These habits may change, however, as the insect becomes adapted to that climate, which is entirely different from the conditions prevailing in the Southwestern States, where the species has thrived for three-fourths of a century.

NATURAL CONTROL.

The known natural enemies of the Mexican bean beetle are relatively few in the Southeastern States. None has been of much economic importance since the insect reached that section, and it

will no doubt require many years for native enemies to become adapted to it. No insect or other enemy has been observed to effect any appreciable control in the western part of the United States.

PREDACIOUS ENEMIES.

The following predacious insect enemies have been observed to prey on the Mexican bean beetle, *Epilachna corrupta*, in the field, and most of these have been observed in confinement.

The common coccinellid beetle, *Megilla maculata* DeG., was very abundant about Birmingham, Ala., during the summer of 1921. This beneficial species fed, in both the larval and adult stages, on the eggs of the bean beetle, and occasionally on young larvæ. Many egg masses were attacked and a few eggs of each destroyed. The bean beetle was so abundant that less than 3 per cent of the eggs were destroyed. During 1922 Megilla was not abundant, and very few eggs were destroyed.

The convergent lady-beetle *Hippodamia convergens* Guér., also eats the eggs of the bean beetle, but sparingly. The adults of *Coccinella sanguinea* L. and *C. novemnotata* Hbst. feed slightly on the eggs, the latter species more generally on younger larvæ. *Adalia bipunctata* L. feeds slightly on the eggs and small larvæ.

A common soldier-bug, *Stiretrus anchorago* Fab., destroys larvæ, pupæ, and beetles. It is not common until late in the season, and then is not sufficiently abundant to be of much value. This bug, both in the last nymphal and in the adult stages, is at present the most effective native enemy.

Another pentatomid bug, *Podisus maculiventris* Say, feeds in both nymphal and adult stages on larvæ, pupæ, and adults of the bean beetle and is a more active feeder than Stiretrus. It is not generally as numerous as Stiretrus, and is therefore less effective. Both of these bugs can subsist for long periods on a bean beetle diet.

The common wheel-bug, *Arilus cristatus* L., feeds on larvæ, pupæ, and beetles, but is too rare to be effective.

The ground beetles might be expected to prey on the bean beetle, especially when the latter is so abundant as to destroy a field of beans and the larvæ crawl about in search of food. No beneficial effects have been observed from this source, though three native species, *Harpalus caliginosus* Fab., *Scarites subterraneus* Fab., and *Calosoma sayi* Dej., eat larvæ sparingly, and the latter two species attack pupæ and beetles in confinement.

The tiger beetles *Tetracha carolina* L., and *T. virginica* L., both larvæ and adults, feed voraciously in confinement on larvæ, pupæ, and adults of the bean beetle and occur in infested fields. It is not certain that they feed voluntarily on this insect in nature, and their habits would not indicate that they are very important enemies. They are not present in numbers in well-cultivated fields.

The larvæ and adults of the lace-wing flies *Chrysopa oculata* Say and *C. rufilabris* Burm. feed on pupæ of the bean beetle. They are not numerous and are of little importance.

In the fall of 1921 a number of instances of feeding by caterpillars on pupæ of the bean beetle were noted. In three instances the larvæ matured in confinement on a diet of bean-beetle pupæ and developed into normal moths, two of which were identified by Dr. F. H. Chittenden as *Prodenia ornithogalli* Guen., and the third as *Laphygma*

frugiperda S. & A. A fourth collected in the field proved to be *Heliothis obsoleta* Fab. (Pl. XI, *C*.) These unusual habits may have been caused by the destruction by the bean beetle of the bean foliage on which these insects had been feeding.

The ants *Solenopsis geminata* Fab. and *Pheidole* sp. destroyed bean-beetle pupæ in experimental cages during the summer of 1921.

The adult of *Epilachna corrupta* has been observed to feed on its own eggs in the field in the presence of green bean foliage, and larvæ have also been observed feeding on pupæ in the presence of other food, but very rarely. In the absence of green foliage, adults and larvæ very commonly feed on pupæ and eggs of the bean beetle, but not to a sufficient extent to be important in natural control.

Not infrequently dead larvæ and pupæ, light brown to dark brown in color, are observed in the field, attached to leaves. Bacteriological examinations of such specimens by Dr. G. F. White showed the presence of unidentified Coccobacillus and Streptococcus. Attempts to inoculate healthy larvæ by spraying cultures, furnished by Doctor White, on bean plants exposed to the larvæ availed nothing. It appears, however, that in the field during the summer a low percentage of larvæ and pupæ succumb to a bacterial disease.

PARASITES.

The Mexican bean beetle has been exceptionally free from parasites in the United States. No internal insect parasites have been recorded heretofore, and none was observed during the season of 1921. In 1922, however, a few native parasites of native insects were reared from the bean beetle.

Phorocera claripennis Macq. (Pl. XI, *A*) was common during July and early August, and a considerable number were reared from egg to adult in cages on third and fourth instar larvæ of the bean beetle during that period, but the species gradually became scarce and disappeared from the field by September 1. The female fly deposits distinct white eggs on the larva. (Pl. XI, *B*.) Only one larva of the parasite completes its development in the host. This species, although the most common native parasite during 1922, did not become abundant enough at any time to effect any appreciable natural control. It has many other hosts.

The sarcophagid fly *Helicobia helicis* Towns.[6] was reared in two instances from bean-beetle larvæ. This general feeder is also rare.

In 1921 Prof. H. F. Wickham collected a puparium of a parasitic tachinid fly in the vicinity of Mexico City, Mexico. In 1922 E. G. Smyth, later in the season, collected numbers of these puparia and shipped them to Birmingham, Ala. The fly occurs very late in the season, but is reported to parasitize 30 to 50 per cent of the larvæ of *Epilachna corrupta* in Mexico. It has been recently described by Dr. J. M. Aldrich as *Paradexodes epilachnae*.[7] More than 300 were successfully reared in the insectary at Birmingham on third and fourth instar larvæ of the bean beetle, and a few were liberated. A considerable number of puparia, also, were held in hibernation. Emergence continued during mild weather in the winter, when the

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[6] Determined by Dr. J. M. Aldrich, of the U. S. National Museum.
[7] Proceedings of the Entomological Society of Washington, vol. 25, No. 4, April, 1923, pp. 95–96.

host was hibernating as an adult, and this habit may make colonization difficult. This parasite appears to be capable of immense benefit.

Phytophagous Coccinellidae in Java, according to Dr. P. van der Goot, entomologist to the Dutch Government, are attacked in the egg, larva, and pupa stages by Hymenoptera; hence it appears that other parasites that may prove useful against *Epilachna corrupta* may be found.

EFFECT OF SUNLIGHT.

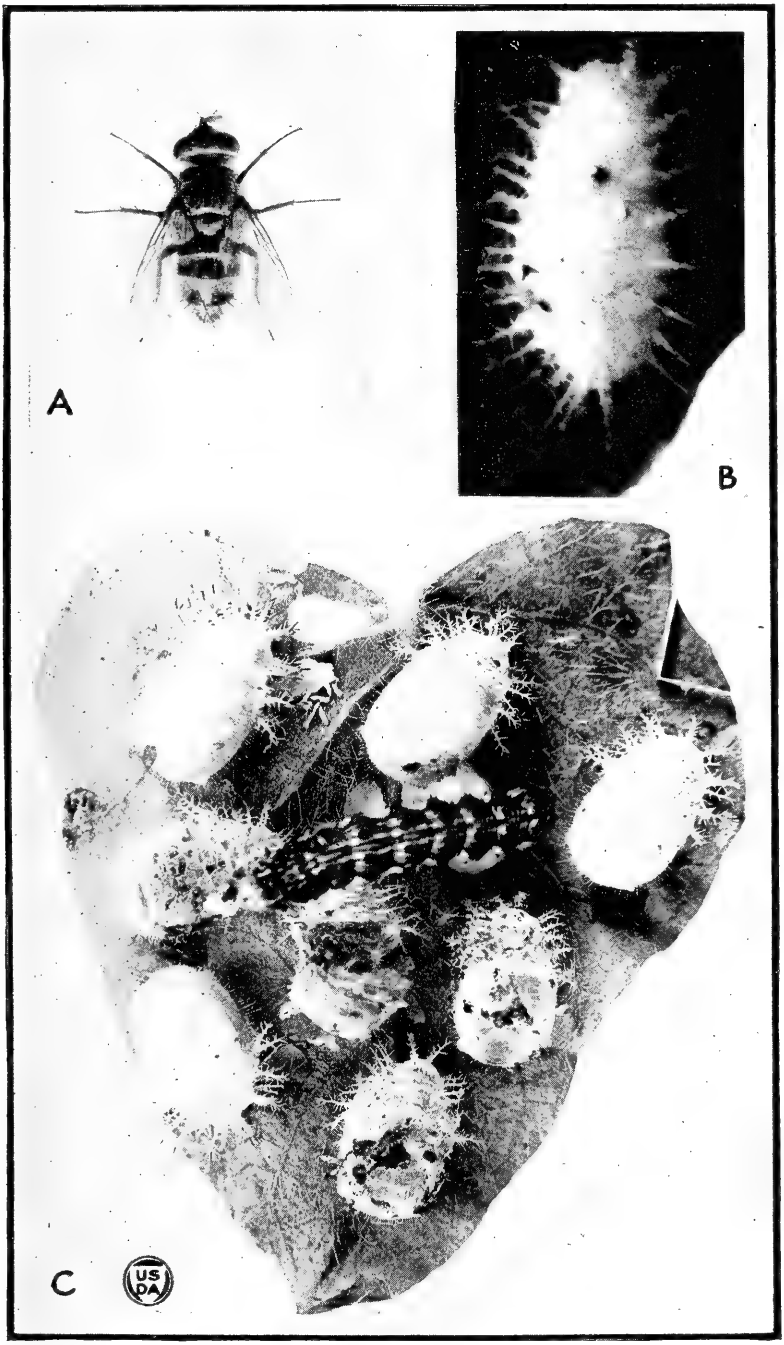
During a prolonged hot dry period in 1921, when bean beetles were so numerous that they destroyed all bean plantings in the Birmingham district, the larvæ were forced to crawl about in search of food, and were also exposed to the sun on the stems and stalks of plants. Pupæ were so numerous that many stalks and pods were literally covered with them, and many larvæ pupated on the ground, or on stones, weeds, or any object at hand. Many thousands of pupæ gradually turned brown and died.

Experiments were performed and various stages of the insect were exposed to sunlight. The eggs, which are normally protected from direct sunlight, are occasionally laid on the upper surface of the leaf, or, when laid on the under surface, may be exposed in some instances by bean leaves growing upward. This is often the case with the tepary bean. An exposure to sunlight for 33 hours on four consecutive days in June killed 57 eggs when the shade temperature ranged from 74° to 94° F., but 15 eggs of a group of 59 hatched after 30 hours' exposure on the same days. Twenty-four groups, totaling 1,240 eggs, exposed to the sun continuously from three to five days during late July and August at shade temperatures reaching a maximum of from 80° to 101° F., succumbed with the exception of two eggs.

An exposure to direct sunlight for two minutes was fatal to first-instar larvæ 1 day old when shade temperatures registered 96° F. Second-instar larvæ, 5 days old, succumbed after seven minutes' exposure to direct sunlight when the shade temperature registered 92° F. Third-instar and fourth-instar larvæ succumbed after 10 minutes' exposure to direct sunlight when the shade temperature registered 93° F.

Three hundred pupæ were collected in the field September 12 and exposed to the sun for two days when maximum shade temperatures each day registered 96° F., and all succumbed, while 78 per cent of a check of 100 pupæ emerged in the shade, and all pupæ reared in the shade in other experiments emerged. Undoubtedly most of the 22 per cent of pupæ of the check lot had been killed by sunlight in the field.

Adults are more resistant, and since they can fly to sheltered places are not usually killed by effect of sunlight. Under conditions of light or medium infestation, large numbers of the various stages of the insect are not exposed and no great benefit from this source occurs. All in all, however, the factors enumerated above, and no doubt others which were not observed, tended to reduce the number of adults going into hibernation to such an extent that the infestation was much lighter in 1922 than in 1921.



ENEMIES OF THE MEXICAN BEAN BEETLE

A, Phorocera claripennis, a native tachinid parasite of the larger larvæ of the Mexican bean beetle, $\times 2\frac{1}{2}$; *B,* eggs of *Phorocera claripennis* on fourth-stage larva, $\times 6$; *C,* corn earworm feeding on pupa of Mexican bean beetle, $\times 4$

BENEFICIAL EFFECT OF SPRAYING FOR THE MEXICAN BEAN BEETLE

A, Untreated check plats of beans destroyed by Mexican bean beetle alongside of plats treated with magnesium arsenate, used as a spray; *B*, same plats as shown in *A*, one week later, after leaves had dropped; sprayed beans to the left

GENERAL METHODS OF CONTROL.

Reduction of the infestation by cleaning up hibernation quarters offers an excellent method of control. In sections where waste lands are sought by the beetle, cleaning up can best be accomplished during the fall or spring by burning. Fence rows and inaccessible portions can be burned effectively by means of a blowtorch designed for the purpose, along the lines of a cactus or pear burner, such as is used in the Southwest for burning spines from prickly pear. It has been discovered that the beetle seeks places somewhat sheltered and where accumulations of leaves, pine needles, or plant débris occur. In such instances the material may be gathered in piles and burned, with especial care to prevent the spread of the fire over woodlands.

Burning can not usually be recommended for the Southeast because of the loss which would result in many sections where woodlands are abundant and are of economic value. Loss of timber, game, and beneficial insects in many cases would exceed the benefit gained, since the value of the bean crop would not equal the loss. Also, the beetle is capable of long flights to hibernation, and the area to be burned would be greater than with many other species of insects. In more densely populated sections, or in sections where the major part of the land is tilled, and where waste places are necessarily sought by the beetle, this practice will undoubtedly be very beneficial. Where woodlands are relatively small, burning of the materials which shelter the beetles may be practiced without detriment to the timber. This practice would require a close community effort over a considerable area, and would be promising only in cases where the area suitable for hibernation is restricted.

Under conditions of severe infestation, fields which are badly injured should be plowed under before the larvæ develop into beetles.

Covering any stage of the beetle with 1 inch or more of clay soil during hot weather destroys it.

The growing of beans under conditions of heavy infestation is impossible without the use of remedial measures. Only as many beans as can be treated should be planted. The expense of treating pole beans, on account of the difficulty of application and the longer period to maturity, which involves more applications, makes it advisable to grow only bush beans where infestation is heavy.

Where green beans are grown, the infested fields should be plowed as soon as the crop is picked. This will destroy large numbers of all stages of the bean beetle and will reduce the infestation. Community effort is essential in this practice, and will benefit each grower.

For the winter months fields should be planted to cover crops best suited to conditions.[8] This will add organic matter to the soil and stimulate a vigorous growth and early maturity the following year, thus tending to compensate for bean beetle injury.

Plant varieties which do not produce large, bushy foliage. Too leafy a foliage can not be as thoroughly covered by arsenicals as varieties which produce less foliage.

Plant seed in the drill. Clumps of plants are more difficult to reach with insecticides than row crops.

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[8] Farmers' Bulletin 1250, entitled "Green Manuring."

ARTIFICIAL CONTROL.

At the outset the problem of artificial control of the Mexican bean beetle appeared to be a matter of the application of the proper stomach poison to the bean foliage. Some experience had been gained along these lines by State and bureau workers in the West and Southwest. The general conclusion from these investigations was that lead arsenate and zinc arsenite are the most satisfactory arsenicals for the control of the Mexican bean beetle, these being recommended as sprays.

INVESTIGATIONS OF 1921.

ARSENICALS.

The work for 1921 was therefore planned with a view to learning what results could be obtained in the Southeastern States by these sprays. A number of other arsenicals were also tried, chiefly calcium arsenate and magnesium arsenate. A large series of experiments was conducted with various dilutions of all of these arsenicals, both as sprays and as dusts. After completing the first experiments, it appeared as though lead arsenate and zinc arsenite were promising materials, since check plats were totally destroyed and excellent protection was afforded treated plats. Experiments were continued, however, and it was soon learned that the plant injury caused by these arsenicals makes them hardly worthy of recommendation to the grower, on account of reduced yields.

Different factors were found to influence this plant injury. Attention was called by Dr. William Moore, formerly of the Bureau of Entomology, and C. M. Smith, Insecticide and Fungicide Laboratory, Bureau of Chemistry, to the effect on lead arsenate of the water available in the Birmingham district. Further experiments were performed, and it was learned that lead arsenate is absolutely unsafe for application to bean foliage, even with distilled water, or diluted with hydrated lime and used as a dust. It was also learned that zinc arsenite causes a serious reduction in yield, even though the injury to the plant is not as noticeable as injury caused by lead arsenate. Experiments proved that calcium arsenate is absolutely unsafe for bean foliage without the application of an excess of lime along with the material. These results were also obtained when the materials were used as dusts.

Throughout all the experiments magnesium arsenate, a commercial preparation which has not been generally used on account of the injury to foliage of different kinds of fruit trees, was found to be safe on bean foliage, even though used with the water of the district, which is relatively high in soluble sodium salts. Under conditions of severe infestation in 1921 unsatisfactory results were obtained with dilutions of those arsenicals which were injurious to foliage in the undiluted state.

Since magnesium arsenate is not generally available to bean growers, and because of the fact that growers in the Southern States were more familiar with dusting methods than with spraying methods, a tentative recommendation was made that calcium arsenate of a high grade be diluted with 9 parts of hydrated lime and be applied to the foliage as a dust. The amount of arsenic in this mixture,

however, was so low that entirely satisfactory results were not obtained under conditions of severe infestation. Magnesium arsenate was therefore recommended because it was the only arsenical known which could be used without dilution and not cause plant injury.

OTHER INSECTICIDES.

Experiments were also conducted with materials other than arsenicals. Nicotine dusts were thoroughly tried. Various strengths of dust were used, ranging from 0.38 per cent nicotine content to 4 per cent nicotine content. The insecticidal properties of these dusts against the Mexican bean beetle were nil.

A number of experiments were performed with pyrethrum powder, used undiluted as a dust and combined with various diluents, such as cornstarch and hydrated lime. Decoctions of pyrethrum powder were also used. It was found that pyrethrum powder and certain decoctions thereof were very toxic to the adult of the Mexican bean beetle, less toxic to the larvæ, and almost ineffective against the eggs and pupæ. Because of the high cost of the material, however, and the frequent applications required, pyrethrum is absolutely impracticable for field control.

A number of new compounds were tried in an experimental way in cooperation with Dr. William Moore and C. M. Smith. While some of these materials may be of value, not one of them has as yet warranted recommendation over some of the better known available arsenicals.

INVESTIGATIONS OF 1922.

The problem presented in the 1922 experiments in artificial control was the use of an arsenical which would not be injurious to bean foliage and at the same time would be sufficiently toxic to the Mexican bean beetle to insure satisfactory control, the former requirements being the more limiting.

Since magnesium arsenate and calcium arsenate with an excess of lime were the most promising arsenicals tested in 1921, these, as well as basic lead arsenate, were used on a larger scale than others.

A few experiments were performed with lead arsenate and zinc arsenite in order to check the results obtained the previous season. A number of other compounds were also the subject of experiment.

SPRAYING AND DUSTING MACHINERY USED IN EXPERIMENTS.

The power sprayer (figs. 11, 12) referred to is a 150-gallon capacity, triplex-pump, high-pressure potato sprayer, equipped with a high-speed 5-horsepower engine, and was used in experiments as a 4-row sprayer, 3 nozzles per row, at 250 pounds pressure.

An arrangement was improvised to permit the driver to raise and lower the boom with one foot when turning around or driving over uneven places.

The wheelbarrow sprayer (fig. 13) is a 15-gallon capacity, hand-operated outfit, capable of maintaining 150 pounds pressure at two nozzles. It was mounted on a narrow slide and pulled by one horse. Two men were required—one to pump and one to spray. The arrangement of the nozzles on a U-shaped pipe attached to the spray rod made it possible to spray a row at the speed the horse walked.

The hand sprayer (fig. 14) referred to is a 3-gallon capacity, compressed-air type, which it is estimated produces from 40 to 65 pounds pressure if pumped at intervals of 100 feet of row.

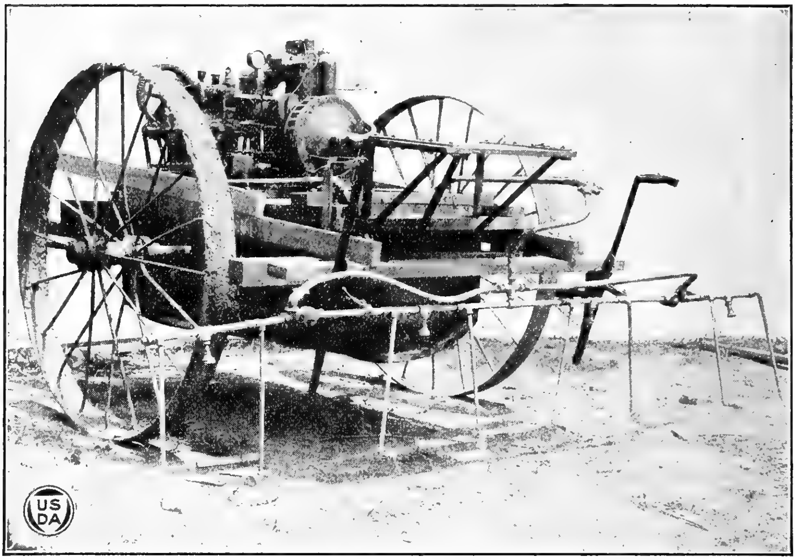

FIG. 11.—Power sprayer used in experiments against the Mexican bean beetle, showing arrangement of nozzles and device for raising the boom.

The knapsack type of hand bellows duster used is illustrated in Figure 15. The power duster used is shown in Figure 16.

FIG. 12.—Spraying beans for the Mexican bean beetle with a power sprayer. This machine may be adapted to spray 8 rows at once.

EXPLANATION OF TABLES.

Table 9 gives only the results of the experiments performed with the arsenicals commercially available, arranged by experiments chronologically. Table 12 gives results of dusting experiments,

arranged by insecticides. Table 13 gives results of spray experiments arranged by insecticides. The infestation was not as severe as in 1921, and comparisons between experiments must take into consideration the degree of infestation.

FIG. 13.—Spraying beans against the Mexican bean beetle with a wheelbarrow sprayer mounted on a slide.

In comparing results with different insecticides, the plant-injury factor as well as the insect-control factor must be taken into consideration. The plant-injury factor is apparent in yields harvested

FIG. 14.—Spraying small field beans with a hand sprayer to control the Mexican bean beetle.

when infestation is light, but in some cases does not show, except by comparison, when yield is heavy. The notes taken during the experiments showing observations of visible injury give very accurate data

on this point. This is shown in experiments performed under conditions of light infestation, with the possible exception of the zinc arsenite experiments. Injury by this insecticide is not easily estimated by observation. When infestation by the Mexican bean

FIG. 15.—Dusting beans with a knapsack bellows type of duster.

beetle is light, variations in yield are attributed to insecticide treatment, which often causes a decrease in yield. Each experiment must be compared with check plats and other plats tested at the same time, because of variations in land, season, and climatic factors.

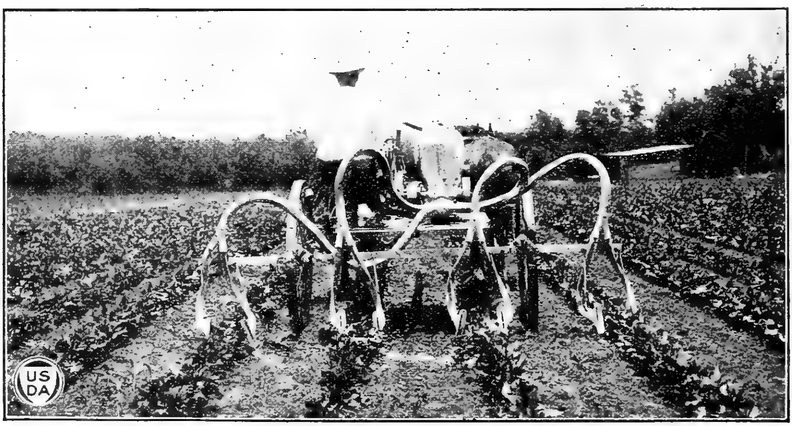

FIG. 16.—Power duster used in experiments in control of the Mexican bean beetle.

Under typical conditions in the Southeast, summer crops of bush beans do not produce well.

In experiments where injury from treatment was serious, beetle injury would not be estimated.

In dust experiments, treatments in some instances followed closely on account of frequent heavy rains.

In experiment 1(c) the pulverized stone lime was not ground sufficiently to obtain a good application, and the amount applied was therefore excessive, as much dust fell to the ground.

The per cent of reduction in yields due to treatment, with the check plat as the basis, does not take into consideration bean beetle injury to the check, for in all experiments where this calculation is made Epilachna injury did not reduce yields to a very great extent. The insecticide injury as affecting yields therefore is shown rather lower in this column than is actually the case, for there is no way of accurately determining the reduction in yield in the absence of insect-free checks.

Check plats, except in a very few instances, were of the same size as the treated plats. In some cases two check plats were used, each the same size as the treated plats.

TABLE 11.—*Experiments with arsenicals commercially available, including sprays and dusts, for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used. (Dusts, pounds of materials; sprays, pounds of materials per 100 gallons rain water, unless otherwise noted.)	Rate applied per acre.	Size of plot.	Date of applications (1922).					Effect on yield, check plat basis.		Injury to foliage.			Infestation.
				1	2	3	4	5	Increase.	Reduction.	Insecticide.	Insect. Treated.	Insect. Check.	
		Gallons.	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
1(a)[1]	Basic lead arsenate 2½ pounds (commercial).	116	0.05						....	....	0	....	40	Medium.
1(a)[1]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	116	.05						....	....	5	0	40	Do.
1(a)[1]	Zinc arsenite 1½ pounds. caseinate of lime 1 pound.	116	.05	Apr. 21	May 6	May 12	May 20	....	....	40	25	0	40	Do.
1(a)[1]	Calcium arsenate 1½ pounds, rock lime 3 pounds.	116	.05						....	25	30	0	40	Do.
1(a)[1]	Lead arsenate 2 pounds	116	.05						....	31	40	0	40	Do.
		Pounds.												
1(b)[2]	Lead arsenate	14	.043						....	59	60	....	25	Light.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 1 pound.	13	.043						....	38	60	....	25	Do.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 4 pounds.	19	.043						....	37	30	....	25	Do.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 9 pounds.	18	.043						....	15	25	....	25	Do.
1(b)[2]	Calcium arsenate	10	.043						....	60	35	....	25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	19	.043	May 6	May 10	May 16	May 20	May 26	....	60	20	....	25	Do.
1(b)[2]	Calcium arsenate 1 pound, pyrethrum powder 1 pound.	18	.043						....	40	35	....	25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 4 pounds.	19	.043						....	30	10	....	25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	18	.043						13	....	0	....	....	Do.
1(b)[2]	Basic lead arsenate	17	.043						18	....	0	0	25	Do.
1(c)[1]	Basic lead arsenate paste[3] 6 pounds	....	.043	May 6	May 12	May 20	....	....	....	....	0	....	....	Do.
1(c)[2]	Calcium arsenate 1 pound, pulverized stone lime 1 pound.		.043	May 16	May 20	May 26	....	....	....	....	55	....	....	Do.
		Gallons.												
2[4]	Lead arsenate 2 pounds	70	.005						....	....	25	5	90	Very heavy.
		Pounds.		May 23	....	....	....	....						
2[4]	Lead arsenate 2 pounds, water from stream.	70	.005						....	....	15	5	90	Do.

3[2]	Calcium arsenate 1 pound, gypsum 1 pound.	15 est.	.004						....	....	15	....	....	Medium.
3[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound.	15 est.	.004						....	....	20	....	....	Do.
3[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 1 pound.	15 est.	.004	May 26	....	....	....	....	....	....	0	....	....	Do.
3[2]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	15 est.	.004						....	....	0	....	....	Do.
4[6]	Lead arsenate 1 pound, hydrated lime 4 pounds.	25	.21						....	56	75	10	70	Heavy.
4[6]	Lead arsenate 1 pound, hydrated lime 9 pounds.	....	.21						23	....	15	10	70	Do.
4[6]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 1 pound.	....	.1						....	16	20	10	70	Do.
4[6]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.21	June 14	June 25	July 7	....	....	15	....	25	10	70	Do.
4[6]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.	....	.1						46	....	10	10	70	Do.
4[6]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	....	.21						60	....	10	10	70	Do.
4[6]	Basic lead arsenate	....	.21						....	3	0	10	70	Do.
5[2]	Lead arsenate 1 pound, hydrated lime 1 pound.	50	.013						....	....	35	25	70	Do.
5[2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	43	.013						....	....	25	25	70	Do.
5[2]	Calcium arsenate 1 pound, pulverized stone lime 1 pound.	53	.025	June 17	June 25	July 10	....	....	....	....	40	25	70	Do.
5[2]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	37	.013						....	....	15	25	70	Do.
5[2]	Zinc arsenite	18	.013						....	....	60	25	70	Do.
		Gallons.												
6[6]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	75–90	.18						1,034	....	0	20	100	Very heavy.
6[6]	Zinc arsenite 1½ pounds, caseinate of lime 1 pound.	75–90	.18	July 1	July 7	July 20	July 27	....	285	....	20	0	100	Do.
6[6]	Basic lead arsenate 2½ pounds (commercial).	75–90	.18						70	....	0	90	100	Do.
6[6]	Basic lead arsenate paste[3] 6 pounds	75–90	.18						356	....	0	80	100	Do.
7[1]	Lead arsenate 2 pounds	80	.033						1,312	....	40	15	100	Do.
7[1]	Zinc arsenite 1½ pounds, caseinate of lime 1 pound.	80	.033						1,715	....	0	15	100	Do.
7[1]	Calcium arsenate 1½ pounds, rock lime 3 pounds.	80	.033	July 1	July 7	July 20	July 27	....	1,715	....	0	15	100	Do.
7[1]	Basic lead arsenate 2½ pounds, caseinate of lime 1 pound.	80	.033						505	....	0	60	100	Do.

[1] Wheelbarrow sprayer used.
[2] Hand knapsack bellows duster used.
[3] Prepared in laboratory.
[4] Hand sprayer used.
[5] Dusting sulphur used in each case.
[6] Power equipment used.

TABLE 11.—*Experiments with arsenicals commercially available, including sprays and dusts, for control of the Mexican bean beetle, 1922*—Contd.

Experiment No.	Insecticide used. (Dusts, pounds of materials, sprays, pounds of materials per 100 gallons rain water, unless otherwise noted.)	Rate applied per acre.	Size of plot.	Date of applications (1922).					Effect on yield, check plat basis.		Injury to foliage.			Infestation.
				1	2	3	4	5	Increase.	Reduction.	Insecticide.	Insect. Treated.	Insect. Check.	
		Gallons.	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
10[2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.012						....	....	25	15	100	Very heavy.
10[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.	....	.012	July 10	July 18	July 21	July 28	....	....	....	20	15	100	Do.
10[2]	Magnesium arsenate	....	.012						....	....	0	15	100	Do.
11[2]	Lead arsenate 1 pound, hydrated lime 1 pound.	....	.004						....	47	30	10	35	Medium.
11[2]	Lead arsenate 1 pound, hydrated lime 2 pounds.	....	.004						11	....	30	10	35	Do.
11[2]	Lead arsenate 1 pound, hydrated lime 3 pounds.	....	.004						136	....	25	10	35	Do.
11[2]	Lead arsenate 1 pound, hydrated lime 5 pounds.	....	.004						46	....	0	10	35	Do.
11[2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	....	.004	July 22	July 28	Aug. 4	Aug. 11	....	206	....	60	5	35	Do.
11[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound.	....	.004						53	....	50	10	35	Do.
11[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 1 pound.	....	.004						141	....	10	10	35	Do.
11[2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.004						189	....	0	15	35	Do.
11[2]	Basic lead arsenate	....	.004						6	....	0	10	35	Do.
12[4]	Lead arsenate 2 pounds	....	.006						72	....	40	10	35	Do.
12[4]	Lead arsenate 2 pounds, water from stream.	....	.006	July 25	Aug. 2	Aug. 10	....	....	....	18	65	0	35	Do.
12[4]	Basic lead arsenate 2½ pounds (commercial).	70	.006						208	....	0	10	35	Do.
		Pounds.												
14[6]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	23	.21						....	38	0	....	....	Very light.
14[6]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.	17	.21						....	([7])	0	....	....	Do.
14[6]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	22	.21						....	([7])	0	....	....	Do.
14[6]	Magnesium arsenate	15	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	....	24	0	....	....	Do.
14[6]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	18	.21						11	....	0	....	....	Do.
14[6]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	22	.21						....	17	0	....	....	Do.
14[6]	Basic lead arsenate	19	.21						....	([7])	0	....	....	Do.

15 [6]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	*Gallons.* 125	.118						38		0			Do.
15 [6]	Zinc arsenite 1½ pounds, caseinate of lime 1 pound.	125	.118							24	0			Do.
15 [6]	Calcium arsenate 1½ pounds, rock lime 3 pounds.	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15		33		0			Do.
15 [6]	Basic lead arsenate 4 pounds, caseinate of lime 1 pound.	125	.118						109		0			Do.
15 [6]	Basic lead arsenate paste [3] 6 pounds	125	.06							4	0			Do.
17 [2]	Magnesium arsenate	*Pounds.* 20	.02						17		0			Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	15	.02						6		0			Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 3 pounds.	14	.02						7		0			Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	17	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		25		0			Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 7 pounds.	13	.02						1		0			Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 9 pounds.	12	.02							17	0			Do.

[2] Hand knapsack bellows duster used.
[3] Prepared in laboratory.
[4] Hand sprayer used.
[5] Dusting sulphur used in each case.
[6] Power equipment used.
[7] Reductions in yields were due largely to inferior crop on one portion of the field due to soil. As noted, no visible injury occurred.

NOTE.—Spray machines were run at the following pressures: Power, 250 pounds; wheelbarrow, 150 pounds; hand, 40 to 65 pounds.

TABLE 12.—*Experiments with dusts for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used.	Rate applied per acre.	Size of plat.	Date of application (1922).					Insecticide injury to foliage.	Reduction in yield due to treatment; check plat as basis.	Bean beetle injury to foliage.		Increase in yield over check plat.	Infestation.
				1	2	3	4	5			Treated.	Check.		
		Pounds	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
1(b)[1]	Lead arsenate, unmixed	14	0.043	May 6	May 10	May 16	May 20	May 26	60	59		25		Light.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 1 pound.	13	.043	May 6	May 10	May 16	May 20	May 26	60	38		25		Do.
5[1]	do	50	.013	June 17	June 25	July 10			35		25	70		Heavy.
11[1]	do		.004	July 22	July 28	Aug. 4	Aug. 11		30	47	10	35		Medium.
11[1]	Lead arsenate 1 pound, hydrated lime 2 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		30		10	35	11	Do.
11[1]	Lead arsenate 1 pound, hydrated lime 3 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		25		10	35	136	Do.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 4 pounds.	19	.043	May 6	May 10	May 16	May 20	May 26	30	37		25		Light.
4[2]	do	25	.21	June 14	June 25	July 7			75	56	10	70		Heavy.
11[1]	Lead arsenate 1 pound, hydrated lime 5 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		0		10	35	46	Medium.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 9 pounds.	18	.043	May 6	May 10	May 16	May 20	May 26	25	15		25		Light.
4[2]	do		.21	June 14	June 25	July 7			15		10	70	23	Heavy.
1(b)[1]	Calcium arsenate, unmixed	10	.043	May 6	May 10	May 16	May 20	May 26	35	60		25		Light.
1(b)[1]	Calcium arsenate 1 pound, hydrated lime 1 pound.	19	.043	May 6	May 10	May 16	May 20	May 26	20	60		25		Do.
5[1]	do	43	.013	June 17	June 25	July 10			25		25	70		Heavy.
11[1]	do		.004	July 22	July 28	Aug. 4	Aug. 11		60		5	35	206	Medium.
1(c)[1]	Calcium arsenate 1 pound, stone lime [3] 1 pound.		.043	May 16	May 20	May 26			55					Light.
5[1]	do.[3]	53	.025	June 17	June 25	July 10			40		25	70		Heavy.
3[1]	Calcium arsenate 1 pound, gypsum 1 pound.	[4] 15	.004	May 26					15					Medium.
3[1]	Calcium arsenate 1 pound, sulphur [5] 1 pound.	[4] 15	.004	May 26					20					Do.
11[1]	do.[5]		.004	July 22	July 28	Aug. 4	Aug. 11		50		10	35	53	Do.
1(b)[1]	Calcium arsenate 1 pound, pyrethrum powder 1 pound.	18	.043	May 6	May 10	May 16	May 20	May 26	35	40		25		Light.
3[1]	Calcium arsenate 1 pound, sulphur [5] 1 pound, hydrated lime 1 pound.	[4] 15	.004	May 26					0					Medium.
4[2]	do.[5]		.1	June 14	June 25	July 7			20	16	10	70		Heavy.
11[1]	do.[5]		.004	July 22	July 28	Aug. 4	Aug. 11		10		10	35	141	Medium.

1(b)[1]	Calcium arsenate 1 pound, hydrated lime 4 pounds.	19	.043	May 6	May 10	May 16	May 20	May 26	10	30		25		Light.
3[1]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	[4] 15	.004	May 26										Medium.
5[1]	do	37	.013	June 17	June 25	July 10			15		25	70		Heavy.
4[2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.		.21	June 14	June 25	July 7			25		10	70	15	Do.
11[1]	do		.004	July 22	July 28	Aug. 4	Aug. 11		0		15	35	189	Medium.
14[2]	do	23	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	38				Very light.
10[1]	do		.012	July 10	July 18	July 21	July 28		25		15	100		Very heavy.
4[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.		.1	June 14	June 25	July 7			10		10	70	46	Heavy.
14[2]	do.[5]	17	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	(6)				Very light.
10[1]	do.[5]		.012	July 10	July 18	July 21	July 28		20		15	100		Very heavy.
1(b)[1]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	18	.043	May 6	May 10	May 16	May 20	May 26	0				13	Light.
4[2]	do		.21	June 14	June 25	July 7			10		10	70	60	Heavy.
14[2]	do	22	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	(6)				Very light.
10[1]	Magnesium arsenate, unmixed		.012	July 10	July 18	July 21	July 28		0		15	100		Very heavy.
14[2]	do	15	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	24				Very light.
17[1]	do	20	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		0				17	Do.
14[2]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	18	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0				11	Do.
17[1]	do	15	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		0				6	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 3 pounds.	14	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		0				7	Do.
14[2]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	22	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	17				Do.
17[1]	do	17	.02	Aug. 16	Aug. 22	Sept. 9	Sept. 15		0				25	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 7 pounds.	13	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		0				1	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 9 pounds.	12	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15		0	17				Do.
1(b)[1]	Basic lead arsenate, unmixed	17	.043	May 6	May 10	May 16	May 20	May 26	0		0	25	18	Light.
4[2]	do		.21	June 14	June 25	July 7			0	3	10	70		Heavy.
11[1]	do		.004	July 22	July 28	Aug. 4	Aug. 11		0		10	35	6	Medium.
14[2]	do	19	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15		0	(6)				Very light.
5[1]	Zinc arsenite, unmixed	18	.013	June 17	June 25	July 10			60		25	70		Heavy.

[1] Hand knapsack bellows duster used.
[2] Power duster used.
[3] Pulverized stone lime used.
[4] Estimated.
[5] Dusting sulphur used in each case.
[6] Reductions in yield were due largely to an inferior crop on a portion of the field due to soil. As noted in preceding column, no visible injury occurred.

TABLE 13.—*Experiments with sprays for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used. (Materials and number of pounds of each per 100 gallons rain water unless otherwise noted.)	Rate applied per acre.	Size of plat.	Date of applications (1922).				Insecticide injury to foliage.	Reduction in yield due to treatment, check plat as basis.	Bean beetle injury to foliage.		Increase in yield over check plat.	Infestation.
				1	2	3	4			Treated.	Check.		
		Gallons.	*Acres.*					*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
1(a)[1]	Lead arsenate 2 pounds	116	0.05	Apr. 21	May 6	May 12	May 20	40	31	0	40		Medium.
2[2]	do	70	.005	May 23				25		5	90		Very heavy.
2[2]	do.[3]	70	.005	May 23				15		5	90		Do.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	40		15	100	1,312	Do.
12[2]	do		.006	July 25	Aug. 2	Aug. 10		40		10	35	72	Medium.
12[2]	do.[3]		.006	July 25	Aug. 2	Aug. 10		65		0	35		Do.
1(a)[1]	Magnesium arsenate 2 pounds, caseinate lime 1 pound	116	.05	Apr. 21	May 6	May 12	May 20	5		0	40		Do.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	0		20	100	1,034	Very heavy.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0				38	Very light.
	Magnesium arsenate 2 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					Do.
	Magnesium arsenate 3 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					Do.
	Magnesium arsenate 4 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 5 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 6 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
16[2]	Magnesium arsenate 8 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 10 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, fish-oil soap 1 pound		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, oil emulsion 1 gallon		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, caseinate lime 1 pound		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds [3]		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
1(a)[1]	Zinc arsenite 1½ pounds, caseinate lime 1 pound	116	.05	Apr. 21	May 6	May 12	May 20	25	40	0	40		Medium.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	20		0	100	285	Very heavy.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	0		15	100	1,715	Do.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	24				Very light.
1(a)[1]	Calcium arsenate 1½ pounds, rock lime 3 pounds	116	.05	Apr. 21	May 6	May 12	May 20	30	25	0	40		Medium.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	0		15	100	1,715	Very heavy.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0				33	Very light.
1(a)[1]	Basic lead arsenate 2½ pounds (commercial)	116	.05	Apr. 21	May 6	May 12	May 20	0			40		Medium.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	0		90	100	70	Very heavy.
7[1]	Basic lead arsenate 2½ pounds, caseinate lime 1 pound	80	.033	July 1	July 7	July 20	July 27	0		60	100	505	Do.

12[2]	Basic lead arsenate 2½ pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	10	35	208	Medium.
	Basic lead arsenate 3 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	10	35	182	Do.
	Basic lead arsenate 3½ pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	15	35	190	Do.
	Basic lead arsenate 4 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	20	35	63	Do.
	Basic lead arsenate 5 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	20	....	....	35	117	Do.
	Basic lead arsenate 6 pounds	70	006	July 25	Aug. 2	Aug. 10	....	20	....	10	35	100	Do.
	Basic lead arsenate 10 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	50	....	....	35	17	Do.
	Basic lead arsenate 2½ pounds[3]	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	15	35	199	Do.
	Basic lead arsenate 10 pounds[3]	70	.006	July 25	Aug. 2	Aug. 10	....	75	....	....	35	8	Do.
15[4]	Basic lead arsenate 4 pounds, caseinate lime 1 pound	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	....	....	....	109	Very light.
1(c)[1]	Basic lead arsenate paste 6 pounds[5]	....	.043	May 6	May 12	May 20	....	0	....	....	....	....	Light.
6[4]	....do.[5]	75–90	.18	July 1	July 7	July 20	July 27	0	....	80	100	356	Very heavy.
15[4]	....do.[5]	125	.06	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	4	....	....	....	Very light.
1(c)[1]	Lead arsenate 1 pound, zinc carbonate 1, 4 pounds	....	.043	May 6	May 12	May 20	....	0	....	....	....	....	Light.
2[2]	....do	70	.005	May 23	....	....	....	0	....	5	90	....	Very heavy.
2[2]	....do.[3]	70	.005	May 23	....	....	....	0	....	5	90	....	Do.
2[2]	Lead arsenate 4 pounds, zinc carbonate 1, 2½ pounds	70	.005	May 23	....	....	....	0	....	5	90	....	Do.
2[2]	....do.[3]	70	.005	May 23	....	....	....	0	....	5	90	....	Do.

[1] Wheelbarrow sprayer used.
[2] Hand sprayer used.
[3] Water obtained from stream.
[4] Power sprayer used.
[5] Prepared in laboratory.

NOTE.—Spray machines were run at the following pressures: Power, 250 pounds; wheelbarrow, 150 pounds; hand, 40 to 65 pounds.

MAGNESIUM ARSENATE.

Magnesium arsenate has proved to be the least toxic to the bean plant of all the materials tested, and it is at the same time toxic to the bean beetle. For two seasons no appreciable injury has resulted from its use in 134 treatments in the field.

As a spray at 2 pounds per acre with caseinate of lime, it has given excellent control. Rain water is not necessary; well water and water from streams do not cause injury to foliage, even though the content of sodium salts is relatively high. When magnesium arsenate was used, increases in yields generally resulted, but slight reductions occurred in a few experiments when bean beetle injury was very light.

Experiment 6 (Table 11) gives a good idea of the merits of this material in comparison with zinc arsenite and basic lead arsenate, and the relative merits of the latter in comparison with calcium arsenate are shown in experiment 7 (Table 11). The check plat in experiment 6 was completely destroyed, while the adjacent plat treated with magnesium arsenate remained green and bore a good crop. (Pl. XII, *A*, *B*.)

Magnesium arsenate is also safe for use as a dust. On account of poor physical properties it should be diluted with from 1 to 5 parts of hydrated lime, depending on the infestation. Further work with this material as a dust is necessary.

This arsenical, as at first placed on the market, was very high in water-soluble arsenic content, but the method of manufacture has been improved and all the results reported herein were obtained with a high grade of material which did not exceed 0.13 per cent water-soluble arsenic content, expressed as metallic arsenic. The toxicity of this material to the Mexican bean beetle compares very closely with that of calcium arsenate. Caseinate of lime as a spreader, added at the rate of half as much by weight as the arsenical, may be used with this material when applied as a spray.

BASIC LEAD ARSENATE.

Basic lead arsenate is probably the safest commercial material for use on bean foliage when mixed with rain water. It does not cause injury to foliage when used as a dust. Its low toxicity to the bean beetle makes it very undesirable. In one instance 90 per cent of the field treated with this material was destroyed, and could hardly be distinguished from the untreated field. Laboratory-prepared material gave similar results. In other instances, under conditions of light infestation, this material gave sufficient protection and yields were notably increased. In one experiment this material was used at the rate of 4 pounds per acre, as a spray, without injury to the bean foliage. Further experiments are necessary to determine the degree of control which can be obtained at this rate of application.

Basic lead arsenate is the commercial basic lead arsenate such as is used in certain districts of California, and is termed "4, 1, 3, 1–lead-hydroxy arsenate, $Pb_4 (PbOH) (AsO_4)_3, H_2O$" by McDonnell and Smith.[9]

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[9] Jour. Amer. Chem. Soc., vol. 38, No. 10, October, 1916, p. 2030.

ZINC ARSENITE.

The two commercial grades of zinc arsenite experimented with the past two seasons are unsafe for use on bean foliage. Zinc arsenite does not appear to be as injurious to bean foliage as lead arsenate. The injury to the bean plant is different from that caused by other arsenicals, as burning of the foliage does not always result, but the plant is visibly stunted, the color of the foliage turns darker green, and the leaves show a tendency to curl.

Used as a spray at 1½ pounds to the acre, reductions in yield below those of check plats were obtained. Under conditions of severe infestation, excellent insect control is apparently obtained, but treated fields do not yield well. On account of the particular type of injury to the crop from use of this arsenical, the injury is likely to be overlooked and the arsenical rated too high unless accurate records of yields are obtained.

Only one experiment was performed with this material as a dust during 1922. Diluted with hydrated lime, plant injury can be reduced, but this material is inferior to calcium arsenate and magnesium arsenate on account of toxicity to foliage. It is also physically inferior to calcium arsenate for dusting.

CALCIUM ARSENATE.

Calcium arsenate or arsenate of lime is extremely toxic to bean foliage. Injury to foliage when used as a dust ranged from 60 per cent to no injury, depending to a great extent on the degree of dilution with hydrated lime. Reductions in yield occurred in much the same order. It is certain that calcium arsenate can not be used as a dust stronger than 1 to 5 parts of hydrated lime, and that appreciable injury may result in some cases with this dilution.

This insecticide is the most desirable for dusting, from the standpoint of physical properties.

Sulphur as a diluent appears to have a slight beneficial effect in reducing plant injury, but not enough to make calcium arsenate safe at stronger than the 1–1–4 dilution shown in the next paragraph, and foliage injury occurred in two experiments to the extent of 10 and 20 per cent, respectively. The beneficial action of sulphur is even less noticeable when calcium arsenate is used in greater proportions.

Excellent results have been obtained with a mixture devised by Dr. F. L. Thomas, of the Alabama Agricultural Experiment Station, comprising 1 part of calcium arsenate, 1 part of superfine dusting sulphur, and 4 parts of hydrated lime. Slight injury, however, has occurred under certain conditions with this mixture. Where this occurs, it is suggested that the hydrated lime content be increased.

Diluted with 9 parts of hydrated lime, the high-grade calcium arsenate used has for two seasons been found safe on bean foliage. Only one instance of injury to foliage occurred, and that only 10 per cent. Further comparisons between this cheap mixture of materials, available to most growers, and the more expensive sulphur mixture are necessary. The slight advantage of this mixture over a 1 to 9 hydrated lime mixture does not warrant the extra expense, where growers have to purchase this mixture already prepared, since the price is from 2 to 4 times as high per unit of arsenical as

a home-mixed material. Where dusting sulphur is available, it is recommended that the grower obtain the ingredients and mix them himself.

Used as a spray, calcium arsenate is unsafe without an excess of lime. At the rate of 1½ pounds per acre, with 3 pounds of rock lime freshly slaked, or hydrated lime, it is comparatively safe. In two experiments no plant injury occurred, and excellent control was obtained. In experiment 1(a) (Table 11) 30 per cent of foliage injury occurred, however, and it should not be used when magnesium arsenate is available. In experiment 7 results identical with those following the use of zinc arsenite were obtained.

The calcium arsenate used in all these experiments was of the very highest grade. The water-soluble arsenic content of this material did not in any case exceed 0.13 per cent, expressed as metallic arsenic. Inferior grades of this compound should be very cautiously applied. The bean plant is more susceptible to arsenical injury than the cotton plant, and grades suitable for cotton dusting may not be suitable for use on beans.

LEAD ARSENATE.

For two seasons lead arsenate proved too injurious to bean foliage to warrant its use in the Southeastern States. Under conditions of severe infestation, the protection afforded the foliage is sufficient to make it appear that good results are obtained, but the arsenical injury is serious enough to reduce greatly the normal yield.

Injury to foliage from lead arsenate used as a dust ranged from 60 per cent with the material undiluted to 15 per cent when diluted with 9 parts of hydrated lime. The reduction in yield ranged from 59 to 15 per cent below untreated checks which were injured by the bean beetle from 25 to 70 per cent. Slight increases in yield resulted from treatment under conditions of medium and heavy infestation when injury by the bean beetle to untreated checks was 35 to 70 per cent. The previous season this material was even more injurious, and experiments were therefore reduced during the second season.

Injury to foliage from lead arsenate as a spray at 2 pounds per acre ranged from 25 to 40 per cent when rain water was used, and from 15 to 65 per cent when water from a stream was used. A reduction of 31 per cent in yield occurred under conditions of medium infestation when the untreated check plat was injured 40 per cent by the bean beetle. It is quite possible that lead arsenate can be used more successfully in the North when the beetle reaches that section, but in the Southeast it is unsafe. Rain water should be used in sections where the water contains soluble salts which decompose lead arsenate and cause an increase in soluble arsenic.

Lead arsenate corrected with zinc carbonate, according to suggestions from Dr. William Moore, may probably be used successfully on beans. Additional work on this point is necessary.

This arsenical is more repellent to the adult bean beetle than magnesium arsenate, zinc arsenite, or calcium arsenate.

The lead arsenate referred to is a good grade of the commercial lead arsenate, or di-lead arsenate, which is termed "dilead orthoarsenate, $PbHAsO_4$," by McDonnell and Smith.[10]

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[10] Jour. Amer. Chem. Soc., vol. 38, No. 10, October, 1916, p. 2030.

USE OF SPRAYED BEANS AS FOOD.

For two seasons beans treated with arsenicals have been analyzed for arsenical deposits. In no case has the amount of arsenic per quart of green snap beans as picked approached the point where there is any danger whatever from consumption of even this amount. Snap beans which have been treated should be washed in two changes of clear water before marketing to safeguard against any difficulty from this source. In accordance with ordinary cleanliness, beans should be thoroughly washed before cooking. There is not the remotest danger from dried beans. Bean-vine hay which has been treated with arsenicals must not be fed to stock.

COST OF TREATMENT.

Computations of the cost of treating an acre of beans, from records obtained on the experimental plats, give results as follows: Spraying costs from $4 to $8 per acre, depending on the costs of arsenicals and type of machine used; dusting costs from $4.50 to $12 per acre, depending chiefly on the prices of arsenicals and the type of machine used. These figures are based on four treatments of bush beans drilled in rows 3 feet apart.

In these calculations, man labor is figured at 20 cents per hour and horse labor at 10 cents per hour. Where labor is higher, calculations may be made to suit conditions. From 4 to 8 hours are required to spray an acre of bush beans with a small hand sprayer, depending on the size of the beans. The wheelbarrow sprayer mounted on a slide and drawn by a horse requires the time of two men and one horse for 3 hours. The power sprayer requires two men and two horses for one-half hour each. The hand duster requires one man for 2½ hours. The power or traction duster requires 25 minutes time of one man and two horses, but this may be reduced on large acreages. Time of refilling machines is included in the above.

DISCUSSION OF ARTIFICIAL CONTROL.

Sprays, compared with dusts, have given consistently superior results for two seasons. Much of the difficulty with dusts is traceable to the manipulation of dusting machinery, which is not at present as suitable for treating the under surfaces of leaves on low crops as spraying machinery.

With the perfection of dusting machinery and methods of application, dusting will probably become a more desirable farm practice in many cases than spraying. Where growers are equipped with machinery for spraying, and are so situated that water can be easily obtained, better results will be obtained by this method. Spraying is not so dependent on weather conditions as dusting, since the adhesion of the spray to the leaf is greater and the material is not washed off the leaves by rains as easily as is the case with the dust. Again, spraying can be done under atmospheric conditions which are unsuitable for dusting. In many cases this makes it possible to obtain better control with one or two fewer applications of sprays than of dusts. The amount of the arsenical required per acre is of course much less with spraying than with dusting, and in view of the increasing price of arsenicals this factor is becoming more and more important.

Spraying has certain disadvantages, compared with dusting. Initial expenditures for equipment are greater in some cases, and more time per acre is required on account of refilling the machine, preparing the spray, and cleaning the nozzles.

Spraying has the distinct advantage that it makes the most efficient and economical use of magnesium arsenate, which is not especially adapted to dusting.

Magnesium arsenate has been found by several investigators to be injurious to the foliage of fruit trees. It will not, therefore, fill the place of an arsenical for general use. A high-grade material, however, will undoubtedly be safe for many uses.

Because of the availability of calcium arsenate and its superior dusting properties, it will be much used, and is recommended as a dust where no better material is at hand. Only a very high grade should be employed, and it should not be stronger than 1 to 9 parts of hydrated lime (or plasterers' lime).

When fine dusting sulphur is available, the 1–1–4 mixture of calcium arsenate, dusting sulphur, and hydrated lime is recommended. If injury to foliage results, the hydrated lime content should be doubled.

Lead arsenate and zinc arsenite should never be used on beans in the Southeast.

MIXING DUSTS.

Dusts may be mixed on the farm with very little trouble. Ingredients should be weighed. Quantities up to 100 pounds may be mixed with a steel drum which can be tightly covered. The drum should be filled not more than two-thirds full, covered tightly, and rolled about for a distance of approximately 50 feet. It should then be tipped up on each end and this process of rolling and tipping repeated 15 or 20 times. When ingredients are lumpy from standing, they should be sifted through at least a 50-mesh sieve before mixing. For large quantities, a ball mill or a baker's sifter and mixer may be used.

SUMMARY OF CONTROL RECOMMENDATIONS.

Magnesium arsenate, at the rate of 2 pounds to 100 gallons of water, is an effective spray. Caseinate of lime as a spreader may be used with this mixture at the rate of 1 pound to every 100 gallons of spray. Using three nozzles to the row on bush beans drilled in rows 3 feet apart, about 90 gallons of spray are required per acre with a power machine drawn by a team. About 2 pounds of the poison per acre is the proper dosage. Two nozzles should be directed to the under side of the leaves, and a pressure of 150 pounds or more is essential for good results. The nozzle over the top of the row need not be used in cases of light infestation or when pressure can not be maintained.

The spray should be applied when the eggs of the bean beetle become numerous, usually when the beans begin to send out their first trifoliate leaves; i. e., the third and fourth leaves.

Under conditions of heavy infestation four applications are necessary at intervals of from 7 to 10 days. Spray may be applied until the first bean pods are 2 or 3 inches long.

When spraying is impracticable, magnesium arsenate may be used as a dust diluted with from 1 to 5 parts of hydrated lime, depending

on the numbers of beetles present and the damage done. Another effective dust is composed of a high grade of calcium arsenate diluted with 9 parts of hydrated lime. A mixture of high-grade calcium arsenate 1 part, fine dusting sulphur 1 part, and hydrated lime 4 parts also is effective and may be substituted for magnesium arsenate when the ingredients are readily available to growers.

On bush beans drilled in rows 3 feet apart, dust should be applied at the rate of 15 pounds or a little less per acre. Dust should be applied when there is no wind blowing and to the under surface of the leaves. Dew is not essential, but best atmospheric conditions usually occur when dew is on the plants.

On small plantings up to 3 acres in size a knapsack type of hand-bellows duster with tube attached to a flexible hose gives best results. On larger plantings up to 5 to 10 acres, a 2-row duster with nozzles arranged to direct the dust to the under surface of the leaves should be used. One dusting to the row is sufficient except in very heavy infestations, when each row should be dusted from both sides. On larger plantings a power or traction 4-row duster is necessary. Beans should be planted in straight rows and at equal distances apart for all control operations where two or more rows are treated at once.

Where the beetle is numerous, bush beans should be planted. Pole beans mature too slowly and require too many applications to make control practicable.

SUMMARY.

The Mexican bean beetle is the most serious insect enemy of edible beans in the portions of the United States which it inhabits. It has long been present in the Southwest, and within the last few years has made its appearance in the Southeast. At the close of 1922 the infestation included portions of seven States in that section, including Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. It is spreading northward rapidly and, as it is capable of long flights, may, in the course of a few years, extend its range over the whole central and eastern part of the United States.

The adult insect, or beetle, is copper-colored, bears eight black spots on each wing cover, and is about one-fourth of an inch long. The female lays orange-yellow eggs in masses of from 40 to 60 on the lower surfaces of the leaves, and in from 5 to 7 days during summer these hatch into small spiny orange-yellow larvæ, which when full-grown are about one-third of an inch long. The larval period is from 16 to 20 days long in summer. The larva transforms to pupa on the lower surface of a leaf, or on near-by weeds or other objects, and emerges as a beetle in 6 or 7 days, requiring in Alabama a total from egg to adult of 27 to 33 days during summer.

The Mexican bean beetle is extremely prolific. A maximum of four generations from first egg to first adult in each generation occurred in 1921 and 1922; that is, the earliest progeny of each generation was reared and four generations were produced. Two generations annually, with a possible third, may be considered the rule in the field, with the peak of the infestation during July and early August.

The beetles and larvæ feed on the under surface of the leaves of beans and other legumes, leaving a characteristic network of tissue,

which soon dries. When beetles are abundant, beans are destroyed in two or three weeks. Since the larva consumes relatively greater quantities of leaf tissue than the beetle, the former is the more destructive stage. In many sections of the South this insect has destroyed entire bean crops in the last two years, and has caused serious damage one year after it has reached a new locality.

Winter is passed by the beetle in woodlands or sheltered places distant from the infested bean field; only a small proportion of over-wintered adults remain in the field. They tend to hibernate gregariously. Most suitable hibernation quarters in the Southeast are on wooded slopes where accumulations of leaves or pine needles offer protection and relatively constant moisture conditions.

The Mexican bean beetle, while primarily a bean pest, is able to reproduce on beggarweed, cowpeas, soy beans, and a few other plants.

Where the bean beetle thrives, control measures are essential.

The bean plant is very susceptible to injury from arsenicals, and care must be exercised in their use. Best results for its control have been obtained with magnesium arsenate, applied as a spray at the rate of 2 pounds to 100 gallons of water, or about 2 pounds per acre, on bush beans drilled in rows 3 feet apart. This arsenical is safe for application to bean foliage and at the same time is sufficiently toxic to kill larvæ and some adults. Caseinate of lime may be used as a spreader at the rate of 1 pound to 100 gallons of spray. About 90 to 100 gallons of spray are required per acre when a large machine is used which directs three nozzles to each row. Two of the nozzles should be directed so that the spray will reach the under side of the leaves. The third nozzle should be directed to the tops of the plants. While this third nozzle is not absolutely necessary, best results have been obtained where three nozzles were used. The spray should be applied at 150 pounds pressure or higher.

Where spraying is impracticable because of lack of water facilities or for other reasons, good results may be obtained by the thorough application of a dust consisting of 1 part of high-grade calcium arsenate and 9 parts of hydrated lime. On small acreages a knapsack bellows duster with a spout attached to a flexible hose is satisfactory. This dust should be applied to the under side of the leaves at the rate of about 15 pounds per acre. Similar results have followed the use of a mixture consisting of 1 part of dry calcium arsenate, 1 part of fine dusting sulphur, and 4 parts of hydrated lime. Dust mixtures can be prepared on the farm more economically than they can be purchased.

Heavily infested fields should be plowed under as soon as the crop is picked. The grower should not plant more beans than he can treat properly. Treatment should begin as soon as the eggs of the bean beetle become numerous, usually at about the time the third true leaf appears on the plant. From one to five applications are required, depending on the degree of infestation, whether light or heavy.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

July 26, 1924.

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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1249

Washington, D. C. ▼ October 27, 1924

FOOD HABITS OF SOME WINTER BIRD VISITANTS.

By Ira N. Gabrielson, *Assistant Biologist, Division of Economic Investigations, Bureau of Biological Survey.*[a]

CONTENTS.

INTRODUCTION.

Every year as winter approaches the majority of the birds that have been present during the summer disappear and their places are taken by other species from the north. With few exceptions these winter visitors have nested either in the mountains or in the northern regions. Some of them are rare, and nearly all are known to the people of the United States only as "winter visitants." These birds tend to be erratic in their movements, being present in a locality in large numbers one season and then perhaps wholly absent for several succeeding years. The crossbills and grosbeaks, which feed to a great extent on seeds of various conifers, are the most erratic, not only in their winter migrations but in the time of breeding as well. Our winter bird visitants have interesting habits and behavior, and as they appear when most other birds are scarce they are especially welcome.

Of the species treated in this bulletin,[1] the pine and evening grosbeaks, redpolls, crossbills, and pine siskins are primarily birds of the

[a] Prepared by the author when a member of the present Division of Food Habits Research.

[1] The species treated in this bulletin include several winter bird visitants the food habits of which have not already been published. Numerous species of the sparrow tribe, for instance, besides those here included, are characteristic winter visitors, but their food habits have already been treated in Biological Survey Bulletin No. 15, The Relation of Sparrows to Agriculture, by Dr. Sylvester D. Judd, 1901. The horned larks have a bulletin to themselves, No. 23 of the Biological Survey, by W. L. McAtee, 1905. The hawks and owls are treated by Dr. A. K. Fisher in Bulletin No. 3 of the Biological Survey, 1893; and in Circular No. 61 of the same bureau, 1907. And a number of the characteristic smaller winter birds are discussed in Farmers' Bulletins Nos. 506 and 630.

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wooded country, and seeds or buds of shrubs and trees form a considerable part of their diet. The snow bunting and longspurs are prairie-feeding species, and the seeds of various grasses and weeds form the bulk of their diet. The pipits are insectivorous.

Discussion of the birds of the woodland group may be dismissed with a few words. Too few stomachs of most of these species collected in summer were available to permit conclusions to be drawn regarding the food for that season. In the winter months, however, during which these birds occur commonly in this country, the evidence goes to show they do little good, and none was obtained from stomach examination to indicate that they do any harm. Few reports of damage inflicted by any birds of these species have been recorded, bud-eating being the only source of complaint. Stomach examination shows, however, that in no case is bud-eating a common habit, but one for which local conditions of the food supply are probably responsible.

As for the snow bunting and the various species of longspurs, it can only be said that what economic importance they are shown to have is in connection with weed-seed destruction. While their consumption of weed seed tends in a desirable direction, it is doubtful whether it accomplishes much real good except locally under unusual circumstances. Usually the birds eat only such seeds as remain on the stalk or on the surface of the ground, and where there is no cultivation many more weeds are likely to sprout and start to grow than can possibly mature. As a result of this, many plants are smothered by the few that survive, and it seems evident that uncultivated ground invariably produces each year the maximum number of mature weed plants that the season, soil, and climatic condition will allow.

Collinge has shown by investigations in England that some at least of the English finches are responsible for the spread of certain weeds, because seeds capable of germination pass through the digestive tract. Judd carried on a few experiments with English sparrows in this country and found that in no case were seeds voided in a condition to germinate. As far as the crossbills, grosbeaks, redpolls, and siskins are concerned there is little chance of seeds being distributed, as these birds have the habit of shelling practically all the seeds eaten. In the case of the longspurs and snow bunting it is believed that from the condition of the seeds in their stomachs, very few are passed in a condition to germinate.

It seems that in this country, while these birds do little or no good from an economic standpoint, they do no damage and may well be left unmolested.

The pipits, on the other hand, are found to be valuable insectivorous birds. The common pipit and the Sprague pipit are similar in appearance and probably have much the same habits, though study material in the case of the latter is as yet insufficient to determine this definitely. The common pipit is found to be a constant natural destroyer of the white grub and the cotton-boll weevil, two of the worst of southern crop pests. It is especially to the interest of southern farmers to protect this bird at all times, as it is one of the most efficient bird enemies of the cotton-boll weevil.

EVENING GROSBEAK (*Hesperiphona vespertina*).

(PLATE I.)

The large beak and the contrasting plumage of yellow, black, and white make the evening grosbeak an easily recognized species. Breeding in the western United States and Canada, during the winter it is occasionally seized with a wandering impulse which carries it east to New York, Pennsylvania, and adjacent States. Usually, however, it chooses to spend this season in the West, wandering over the country in flocks of varying numbers.

For the study of the food habits of this grosbeak, 127 stomachs collected in 14 States and Canada were available. Of these 88 were taken in the winter months (October to March, inclusive), or at the time when the birds commonly appear about human habitations. The remaining 39 were taken in summer.

Winter food.—Ornithologists who have been fortunate enough to observe this interesting bird report that the chief elements in the diet are various kinds of wild fruit, seeds of ash, maple, box elder, and conifers, and buds. Except for this last item these observations are verified by stomach examination. No buds were found in the stomachs, and this seems to indicate that the bud-eating habit is not so general as has been supposed. It is worthy of note that about 50 stomachs taken in Ontario in the winter of 1889–90, and examined by various members of the Canadian Institute, contained no buds.[2] It was found that seeds of several different trees and shrubs constituted the food supply of the birds while they remained in that locality.

No trace of animal matter was found in the 88 winter stomachs, seeds and fruit constituting the entire contents. Seeds of wild fruits formed 39.63 per cent; winged seeds (maple, ash, and box elder), 37.96 per cent; coniferous seeds, 14.5 per cent; and miscellaneous seeds, mast, and rubbish, the remainder. The most important seeds of wild fruits in the food for this period were cherry pits (*Prunus*), found in 23 stomachs and amounting to 17.48 per cent of the total food; dogwood (*Cornus*), identified in 63 stomachs, 13.77 per cent; mountain-ash (*Sorbus*), taken from 13 stomachs, 3.82 per cent; and snowberry (*Symphoricarpos*) in 11 stomachs, forming 1.77 per cent of the food of the 88 birds. Of the winged seeds, ash seeds (*Fraxinus*) were found in 4; maple (*Acer*) in 30; and box elder (*Acer negundo*) in 13 stomachs. Juniper berries had been eaten by 14 birds, and seeds of other conifers by 13.

The nature of the contents of certain stomachs of this species gives a vivid idea of the shearing or crushing power of the beak. The seeds of cherries were broken easily and a whole one was rarely found. The flattened seeds of snowberry were split longitudinally in nearly every case.

Summer food.—The food for the summer season, as determined by an examination of 39 stomachs, is 20.82 per cent animal and 79.18 per cent vegetable matter.

The vegetable food was of much the same character as that taken during the winter season. Seeds of wild fruits are 37.87 per cent of the food for the summer compared with 39.63 per cent during

[2] Trans. Canadian Inst., vol. 3, p. 124, 1891–92.

the winter. The greatest difference is in the relative quantities of winged seeds and those of conifers. The percentage of the latter rises from 14.5 per cent during the winter to 28.45 per cent in summer, while in the case of winged seeds the amount taken falls from 37.96 per cent in winter to 2.79 per cent in summer. This variation is easily understood by considering the habits of the evening grosbeak. During the winter the birds spread over the Northern States into localities where maples, ashes, and box elders are very common and conifers relatively scarce; during the breeding season they frequent coniferous forests, where seeds of these forms are easily obtained. Weed seed and rubbish complete the vegetable food.

Beetles and caterpillars are the chief animal food, although small wasps and ants (Hymenoptera), bugs (Hemiptera), and spiders were also eaten. Among the beetles were found a few of the useful predacious ground beetles (Carabidae), which, however, amounted to less than 1 per cent of the food. Similar small quantities of weevils and click-beetles, both harmful forms, had been taken. The bulk of the beetles eaten was of the leaf-eating scarabaeid genus *Dichelonycha*, which feeds on pine, willow, hickory, and other trees and shrubs. One bird had taken 41 of these beetles and another, 10. Caterpillars to the extent of 11.49 per cent of the total food had been devoured; and as caterpillars with few exceptions may be classed as harmful, this may be counted in the bird's favor.

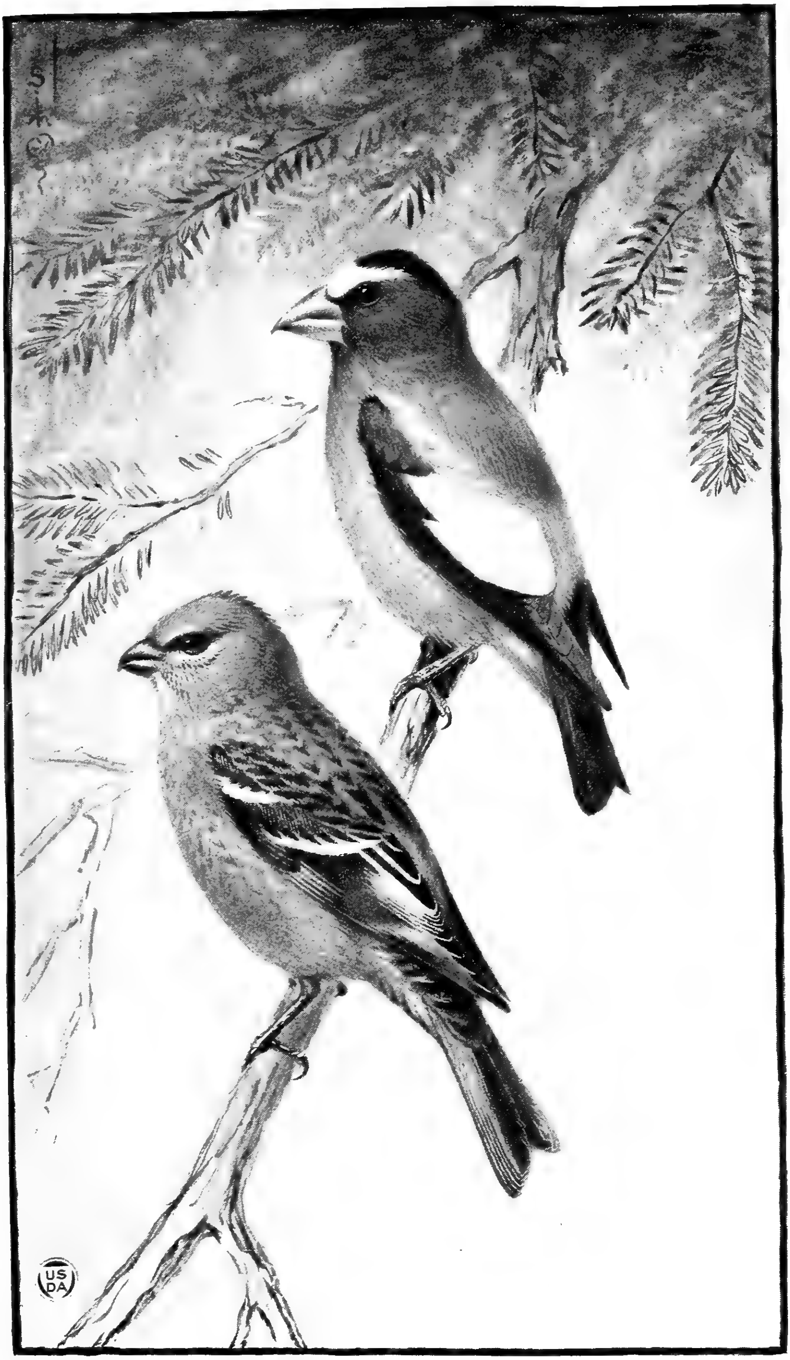
Conclusions.—The evening grosbeak is of little economic importance. Its food consists largely of the seeds and fruits of various trees and shrubs, none of which are of any material value to man. It might turn its attention to cultivated fruits if they were grown in its summer home, but neither this possibility nor the slight harm done by bud-eating justify an unfavorable attitude toward the species.

Food items of the evening grosbeak, identified to the genus or species, as determined by the examination of 127 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Pinaceae.	
Pinus ponderosa (western yellow pine)	11
Juniperus monosperma (cherrystone juniper)	2
Juniperus sp. (juniper)	12
Rosaceae.	
Rubus sp. (blackberry)	3
Malaceae.	
Malus malus (apple)	1
Sorbus sp. (mountain-ash)	14
Amelanchier sp. (serviceberry)	4
Amygdalaceae.	
Prunus sp. (wild cherry)	26
Anacardiaceae.	
Rhus trilobata (skunkbush)	1
Aceraceae.	
Acer sp. (maple)	35
Acer negundo (boxelder)	11
Rhamnaceae.	
Ceanothus sp. (Jersey-tea)	1
Malvaceae.	
Hibiscus sp. (mallow)	2
Cornaceae.	
Cornus occidentalis (dogwood)	1
Cornus sp. (dogwood)	67
Oleaceae.	
Fraxinus sp. (ash)	4
Solanaceae.	
Solanum sp. (nightshade)	1
Caprifoliaceae.	
Symphoricarpos sp. (snowberry)	11
Sambucus (elder)	1



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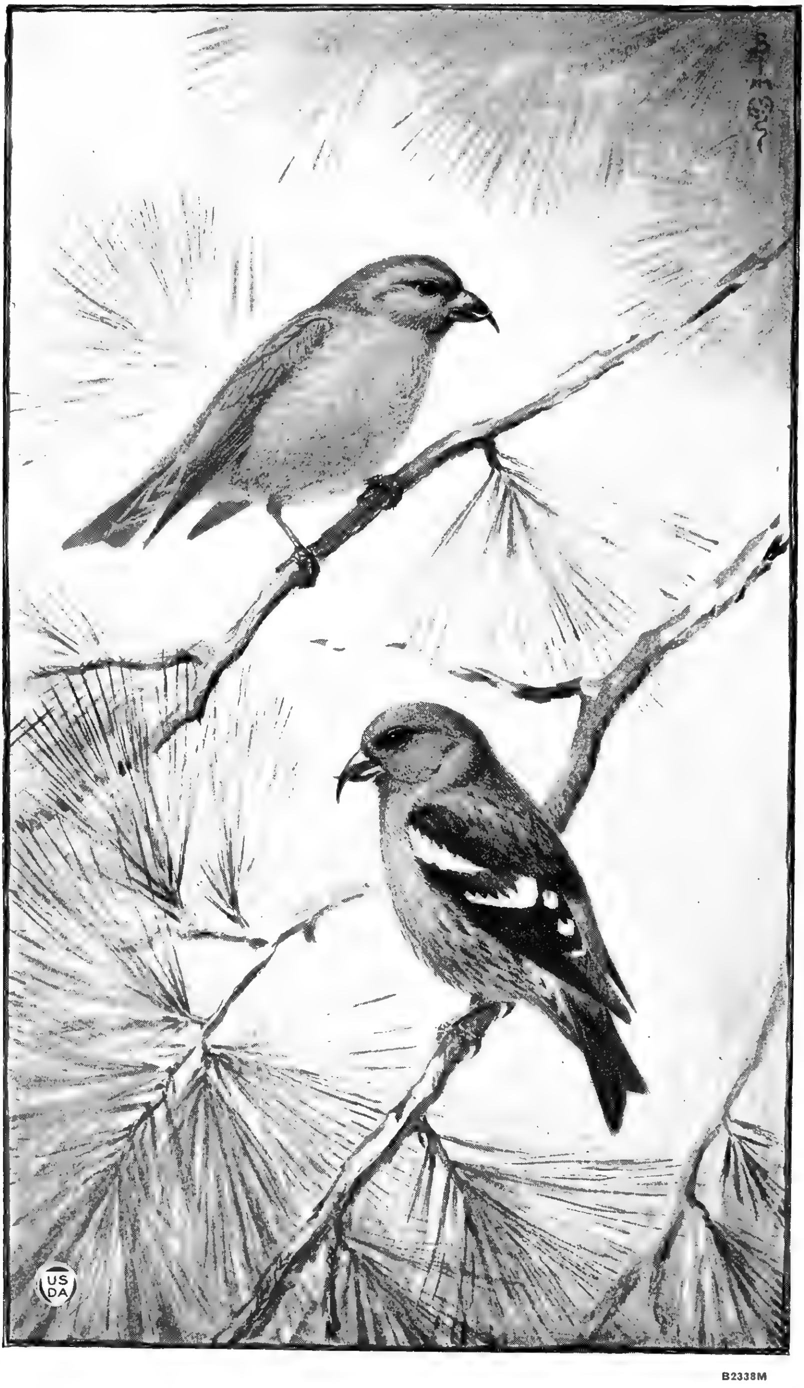
PINE GROSBEAK (UPPER FIGURE) AND EVENING GROSBEAK (LOWER)



B2338M

RED CROSSBILL (UPPER FIGURE) AND WHITE-WINGED CROSSBILL (LOWER)

ANIMAL FOOD.

Lygaeidae (chinch bugs, etc.).	
Nysius sp	1
Carabidae (ground-beetles).	
Platynus sp	1
Scarabaeidae (leaf-chafers, dung-beetles, etc.).	
Dichelonycha sp	2
Lucanidae (stag-beetles).	
Platycerus quercus	1
Tenebrionidae (darkling-beetles).	
Blapstinus sp	1

PINE GROSBEAK (*Pinicola enucleator*).

(PLATE I.)

The handsome red and slate-colored pine grosbeak, a bird breeding in the Canadian forests, in Alaska, and in the mountains of the United States, also appears in the lower areas of the Northern States in winter. As is the habit of several other species discussed in this bulletin, the pine grosbeak wanders more or less irregularly about the country in flocks of considerable size. This species is widely distributed in northern parts of both the Old and New Worlds.

For the study of the food habits of this grosbeak 394 stomachs collected in 13 States, Alaska, and 5 Provinces of Canada were available. Of these, 365 were collected during the winter months and only 29 during the summer season (April to September, inclusive). On account of this unequal seasonal distribution of the material and the fact that this species is of more importance in this country during the winter, the food habits of the pine grosbeak for the two seasons are considered separately.

Winter food.—One of the most striking features of the literature pertaining to the diet of this species is the number of apparently contradictory statements as to its food preferences. A number of different writers refer to its fondness for buds; John O'Leary [3] states that it feeds principally on mountain ash berries; Ernest Thompson Seton [4] confirms this and adds the seeds of black ash as another favorite food. E. A. Mearns [5] reports that the seeds of maple and red cedar berries are the staple articles of diet, but adds seeds of conifers and weeds, frozen apples, and all kinds of berries and buds as other elements eaten. Elliott Coues [6] believes that its principal food is pine seed supplemented by seeds of birch and alder; and Baird, Brewer, and Ridgway [7] state that red cedar berries were the chief food in eastern Massachusetts during the winter of 1835, and record the grosbeak as doing considerable damage in 1869–70 to the fruit buds of apples and pears. William Brewster,[8] in a discussion of a flight of this species into eastern Massachusetts, gives a table of the food items in which are included the seeds of ash, various conifers, apples, waxwork, ailanthus, weeds, and grass; buds of maple, ash, conifers, and a few other trees; and soft fruits of apple, moun-

[3] Forest and Stream, vol. 16, p. 28, Feb. 10, 1881.
[4] The Auk, vol. 7, p. 211, April, 1890.
[5] Bul. Essex Inst., vol. 2, p. 201, 1879.
[6] Birds of the Northwest, p. 105, 1874.
[7] North American Birds, vol. 1, p. 455, 1875.
[8] A remarkable flight of pine grosbeaks (*Pinicola enucleator*), The Auk, vol. 12, pp. 245–256, July, 1895.

tain ash, black alder, honeysuckle, and other shrubs. He also states (p. 251)—

the chief food of the grosbeaks consisted of the seeds of the white ash (*Fraxinus americana*) and of the apple, the fruit of the apple and of the American and European mountain ash (*Pirus americana* and *Pirus aucuparia*) and of the buds of the sugar maple (*Acer saccharinum*), and Norway spruce (*Abies excelsa*). The birds apparently attacked the fruit and buds of other plants only when the supply of their favorite food was exhausted.

As nearly all the above-mentioned items were found in the stomachs examined, the apparent contradictions may be explained by a consideration of the feeding habits of the birds and the locality in which they were observed. In common with the evening grosbeak and the two species of crossbills, the pine grosbeak feeds in flocks which usually settle down in one tree or more and feed for some time, making a full meal on the one variety of fruit or seed if not disturbed. Local conditions, such as relative abundance and availability, probably govern the selection of food. For example, a series of stomachs from New Hampshire contained little except seeds of blackberries (*Rubus*) and the staminate flower buds of pine. When both gizzard and gullet were examined it was usual to find the gizzard filled with one of these foods and the gullet with the other. This would indicate that the readily available food supply in the locality was limited to these two items and that the birds in feeding were making a full meal on one or the other. Stomachs of a second series from British Columbia were filled with the seeds of snowberry (*Symphoricarpos*).

Other similar instances might be cited, each indicating that an examination of the stomachs from either locality alone would result in an incorrect conception of the food of the species. With 365 stomachs collected from a wide territory for the basis of the discussion of the pine grosbeak's winter diet, this difficulty is largely overcome.

The winter food of the pine grosbeak is almost exclusively vegetable, 99.1 per cent of the entire diet being derived from the plant world. In considering the results of the examination of the 365 stomachs, two items stand out because of their relatively high percentages, and the large number of stomachs in which they occurred. These two were *Rubus* seeds and coniferous buds. The seeds occurred in 207 stomachs and amounted to 14.37 per cent of the total winter food. Buds were found in 166 stomachs and made 24.22 per cent of the season's food. Both had been taken from many different regions by birds which were collected in every winter month. Practically all buds were the staminate flower buds of pine, although a few leaf buds and buds of spruce (?) were included in this item. Two hundred and seventeen winter stomachs contained one or both of these foods, which together constituted 38.59 per cent of the total contents. It is apparent from these data that the fruit of *Rubus* and buds of conifers are the staple winter food of this species.

Other items show high percentages, but this is because they constitute the entire content of a few stomachs from one locality rather than because there is a general use of the food over an extended area. A conspicuous example of this is the snowberry, which amounted to 17.3 per cent and had been eaten almost exclusively by 69 birds from one place. Weed seeds formed 7.67 per cent of the

diet, of which seven stomachs from Ontario filled with these seeds contributed half. Juniper berries and other coniferous seeds, amounting to 4.15 per cent, were mostly obtained by birds collected in Connecticut, and birds from Ontario and Massachusetts had eaten most of the maple (2.78 per cent) and ash (1.25 per cent) seeds taken.

A great variety of wild fruit contributed 14.34 per cent of the food supply. The fruits most often found and the number of stomachs in which they were identified were thornapples (*Crataegus*) in 19, dogwood (*Cornus*) in 38, mountain-ash (*Sorbus*) in 14, huckleberries (*Gaylussacia*) in 13, blueberries (*Vaccinium*) in 8, crowberries (*Empetrum nigrum*) in 21, and blackhaws (*Viburnum*) in 7. Most of these fruits were eaten probably for the seeds, as very little pulp was found. The fruit pulp of mountain-ash, crowberries, and blueberries, however, was frequently taken.

Mast amounted to 5.66 per cent of the food and probably was composed largely of beechnuts or acorns. Clarence Birdseye has observed the species feeding freely on beechnuts, but this does not seem to be a common habit.

Although some complaint concerning bud eating by the pine grosbeak has been made, stomach examination fails to show that the habit is general. Thirty-eight birds had taken buds (other than those of conifers) in varying quantities, to the extent of 4.72 per cent of the winter diet. A series of stomachs from Colorado contained buds of willow (*Salix*), and a few birds from various localities had eaten those of maple (*Acer*). While these figures show that relatively few buds are eaten by the pine grosbeak, the possibility of local damage is recognized. A large flock of these birds might do considerable injury in an orchard. Such a possibility does not, however, justify a general condemnation of the bird, as local methods of control can be readily adopted.

Eating frozen apples either for the sake of the seed or pulp is another habit which has often been noticed. Stomach examination, even of birds labeled " feeding on frozen apples," fails to confirm these observations, although a few fragments of seeds and pulp not positively identified might have been apple. The pine grosbeak undoubtedly takes such food, at least occasionally; and if the gullets as well as the gizzards of birds collected while in the act of eating frozen fruit had been preserved, such material would probably have been found. Bits of pine needles, wood, grass, and fragments of unidentified seeds (2.64 per cent) complete the vegetable food.

The animal food taken in winter is of little importance, amounting to only 0.9 per cent of the total. Fragments of small beetles, hymenopterans, and flies, together with weevil larvae, are the chief items, and as they were nearly all found in the coniferous buds it seems certain that they were accidentally devoured with such food.

Summer food.—With only 29 stomachs collected in this season, the material is too scanty to justify monthly averages, and the entire number will be considered together. Of the contents of these stomachs, 16.17 per cent was animal food and 83.83 per cent vegetable.

The vegetable food differs from that taken during the winter months chiefly in the absence of maple and ash seeds and in a higher percentage of wild fruit. *Rubus* seeds and flower buds of pine, which are the staple articles of diet in winter, were found in seven stomachs

and amounted to 7 per cent of the summer food. Seeds of conifers (particularly spruce) amounted to 12.37 per cent, and weed seed to 19.97 per cent of the contents of these stomachs. Wild fruits of many kinds enter into the diet at this season and amount to 32.8 per cent. Buds of deciduous trees, mast, and miscellaneous items complete the list of vegetable matter.

The animal food was very finely comminuted and could not be specifically identified. Grasshoppers, ants, spiders, and caterpillars constituted the bulk of it (15.08 per cent), and small flies and beetles the remainder.

Conclusions.—The pine grosbeak has only one questionable habit, that of eating buds. Examination of 394 stomachs shows that a large portion of the buds taken are coniferous, of no economic importance; these, with wild fruit, furnish this bird practically all its food. The high percentage of wild fruit taken indicates that if this species should come within reach of cultivated small fruits, these would probably suffer. Under present conditions this is not likely to happen, and the species should be protected because of its beauty and the interest aroused by its appearance.

Food items of the pine grosbeak, identified to the genus or species, as determined by the examination of 394 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Buds.	
Pinaceae.	
Pinus sp. (pine)	168
Salicaceae.	
Salix sp. (willow)	11
Aceraceae.	
Acer sp. (maple)	2
Seeds and fruits.	
Pinaceae.	
Pinus flexilis (limber pine)	1
Picea sp. (spruce)	3
Juniperus virginiana (red-cedar)	3
Thuja sp. (arborvitae)	1
Cyperaceae.	
Carex sp. (sedge)	2
Smilacacae.	
Smilax sp. (greenbrier)	1
Iridaceae.	
Iris sp. (iris)	1
Polygonaceae.	
Rumex sp. (dock)	1
Polygonum sp. (smartweed)	21
Amaranthaceae.	
Amaranthus sp. (pigweed)	1
Portulacaceae.	
Montia sp. (water-chickweed)	2
Papaveraceae.	
Argemone sp. (prickly poppy)	1
Brassicaceae.	
Brassica sp. (mustard)	1
Barbarea sp. (winter cress)	51
Grossulariaceae.	
Ribes sp. (currant)	1
Rosaceae.	
Potentilla sp. (cinquefoil)	2
Fragaria sp. (strawberry)	2
Rubus sp. (blackberry)	212
Malaceae.	
Sorbus sp. (mountain-ash)	15
Amelanchier sp. (service-berry)	2
Crataegus sp. (redhaw)	19
Amygdalaceae.	
Prunus sp. (wild cherry and plum)	2
Empetraceae.	
Empetrum nigrum (crow-berry)	24
Anacardiaceae.	
Rhus glabra (smooth sumac)	1
Aceraceae.	
Acer sp. (maple)	23
Elaeagnaceae.	
Lepargyrea canadensis (buf-faloberry)	2
Lepargyrea argentea (buf-faloberry)	1
Araliaceae.	
Aralia nudicaulis (wild sar-saparilla)	2
Cornaceae.	
Cornus canadensis (bunch-berry)	14
Cornus sp. (dogwood)	26
Ericaceae.	
Rhododendron lapponicum	1

Vacciniaceae.	
Gaylussacia sp. (huckleberry)	13
Vaccinium sp. (blueberry)	11
Oleaceae.	
Fraxinus sp. (ash)	7
Solanaceae.	
Solanum sp. (nightshade)	1
Caprifoliaceae.	
Lonicera involucrata (bearberry honeysuckle)	4
Lonicera sp. (honeysuckle)	2
Caprifoliaceae—Continued.	
Symphoricarpos sp. (snowberry)	68
Viburnum sp. (blackhaw)	7
Ambrosiaceae.	
Ambrosia elatior (ragweed)	3
Ambrosia sp. (ragweed)	31
Cichoriaceae.	
Leontodon taraxacum (dandelion)	2
Hieracium sp. (hawkweed)	1

ANIMAL FOOD.

Acridiidae (grasshoppers).	
Melanoplus sp.	2
Chrysomelidae (leaf-beetles).	
Syneta sp.	1
Vespidae (wasps).	
Vespula sp.	1
Formicidae (ants).	
Camponotus sp.	3

RED CROSSBILL (*Loxia curvirostra*).

(PLATE II.)

The red crossbill is a northern breeding species, which in the United States nests regularly only in mountains; but more or less irregularly elsewhere, mostly in the Northern States. It is nomadic and may appear in any part of the country at almost any season, but is much more common in winter. While it occurs with a certain degree of regularity only in the Northern and Western States, it has wandered south to Florida and other Gulf States. The dull red (male) or yellow (female) body, dusky wing and tail, and peculiar crossed mandibles make this species conspicuous and easily recognized.

As erratic in its nesting habits as in its winter wanderings, the crossbill breeds at various dates from January to July or later in many widely scattered localities. W. B. Barrows[9] has suggested that the availability of coniferous buds and seeds throughout the year in favored regions makes it possible for this bird to breed at any season. This variation in the breeding season may in some measure account for its unexpected appearance in other localities where it is observed in wandering flocks at irregular intervals. It will usually be found feeding on conifers, the seeds of which are cleverly extracted from the cones by the crossed mandibles. After a few days or weeks thus spent in one locality the birds will suddenly disappear, possibly not to return for many years.

Little attention has been given to the food of this species, and with one or two exceptions writers have been content merely to refer to its fondness for the seeds of conifers. For this reason it is necessary to depend almost entirely on the examination of stomachs for information on its food habits. Two hundred and forty-three stomachs, collected in 17 States, the District of Columbia, and Canada, were examined. They were very irregularly distributed, both seasonally and geographically. New York, the District of Columbia, Virginia, Florida, and Wyoming are well represented, while comparatively little material is available from the other States. The six months from November to April are represented by 202 stomachs,

[9] Michigan bird life, p. 471, 1912.

and the remaining six months by 41. In view of this unequal seasonal distribution, the winter and summer food habits are considered separately.

Winter food.—The fondness of the red crossbill for the seeds of conifers, which has been noticed and commented on by almost every ornithologist who has observed its feeding habits, is borne out by stomach examination. Seeds of conifers, almost the entire contents of 195 stomachs, amounted to 96.47 per cent of the winter food. Practically every seed was shelled, even the thin inner seed coat being removed, leaving only the soft white endosperm and embryo. As the contents of the distended esophagus also were examined when available, the seeds were seen before they had been crushed or digested to any appreciable extent. The condition of these seeds furnishes an admirable illustration of the dexterity with which the peculiar mandibles of this species are used, as many stomachs were filled with seeds that were not scratched or broken in any way during the removal of the seed coats.

The variation in the food of this crossbill seems to be geographical rather than seasonal, and the species of seeds of conifers recognized were from the few that had been swallowed without being hulled. Pines (*Pinus* spp.) are the ones best represented. Seeds recognized as belonging to this genus comprised 78.29 per cent of the food during the winter. That scrub pine (*P. virginiana*) and western yellow pine (*P. ponderosa*) were the species most commonly found was to be expected, as the majority of the stomachs were collected in localities in which these trees predominated. White pine (*P. strobus*) and red pine (*P. resinosa*) also were identified. Other conifers recognized were spruce (*Picea mariana* and *Picea* sp.) and hemlock (*Tsuga canadensis*).

One stomach collected in March was filled with seeds of ragweed (*Ambrosia elatior*) and two contained chiefly mast, 100 and 80 per cent of the contents, respectively. Other vegetable food included bits of wood, pine needles, and a few small fragments of unidentified seeds.

Animal matter amounted to only 1.07 per cent of the winter food and was composed of spiders (found in two stomachs to the extent of 30 and 20 per cent, respectively), caterpillars (in three stomachs, forming 100, 20, and 10 per cent of the contents), and fly larvae in two stomachs (100 and 50 per cent). Probably all these were picked from conifers; and this was certainly true of one caterpillar, as it had been feeding on pine needles.

Summer food.—The material collected during the months from May to October, inclusive, is too scanty to furnish a satisfactory basis for computing monthly food averages. Tabulation of the contents of the 41 stomachs representing this period shows that the percentage of animal food is 18.02 and vegetable food 81.98, compared with 1.07 per cent and 98.93 per cent, respectively, for the winter months.

Coniferous seeds, constituting 68.34 per cent of the total contents, were found in 31 stomachs. The following species were identified: Western yellow pine (*Pinus ponderosa*), shortleaf pine (*P. echinata*), Engelmann spruce (*Picea engelmanni*), and a larch (*Larix*). Seeds of a sedge (*Scirpus*) and of one of the sunflower family (Asteraceae) furnished 1.69 per cent of the food. Unidentified

wild fruit pulp and skins (the entire contents of two stomachs), 4.88 per cent, and rubbish (two stomachs full of bits of wood and other débris and a third partly filled), 7.07 per cent, complete the list of vegetable food.

Coleoptera, both adults and larvae, found in small quantities in six stomachs, made up 2.09 per cent of the summer food. With the exception of one wireworm, the larvae were those of weevils found within the pine seeds. Fragments of Hymenoptera were identified in two stomachs, but they did not amount to as much as 1 per cent of the contents of either. Hemiptera had been taken by eight birds to the extent of 6.56 per cent of the food. Plant-lice (Aphididae) filled one stomach and in three others occurred in smaller quantities. Several birds had eaten spittle insects (Cercopidae). Caterpillars and one moth formed 8.65 per cent of the food. An insect gall found in one stomach and a number of insect eggs in another complete the animal matter.

It is evident that a larger number of stomachs collected at this season would have added other items to the food of the crossbill, as the variety in the diet was considerably greater than in winter. O. W. Knight[10] has listed the following, in addition to the seeds of conifers, as entering into the food of this species: Beetles, ants, plant-lice, larvae of *Vanessa antiopa* (a spring butterfly), and other insects; buds of elm, maple, birch, alder, poplar, and willow; and seeds of birch and alder. He states also that these birds have been reported as feeding on scraps from salt pork barrels.

Otho C. Poling[11] has observed the birds feeding on frozen apples and on buds of cottonwood; Mary Mann Miller[12] saw them feeding on larvae of the forest tent caterpillar (*Clisiocampa disstria*); Thomas McIlwraith[13] has recorded their eating seeds of sunflowers and digging seeds from a squash left out during the winter; and R. P. Currie, of the Bureau of Entomology, also reports them as feeding on sunflower seeds in a North Dakota garden (August 17, 1891).

Both Dr. A. K. Fisher and Merritt Cary have noted crossbills feeding on the ground, picking seeds from fallen cones; and the former has watched them carry small cones to a low branch and hold them while extracting the seeds. Dr. C. Hart Merriam has observed them feeding on beechnuts; C. E. Ward has seen them eating hemp seed; F. S. Dace has reported them feeding on elm seeds; and A. H. Phillips states that he has watched one devouring the fruit of the flowering crab (*Pyrus floribunda*).

Little complaint of damage by this bird has ever been made. A. L. Reed reports that in Broome County, N. Y., in April and May of 1884 the red crossbills did considerable damage to buds of apple, pear, and cherry trees. Townend Glover[14] states that they did considerable damage in the northerly localities by tearing open apples to obtain the seeds. F. H. King[15] says that in midsummer of 1868 the crossbills appeared in great numbers in western Maine and proved very destructive to oats, disappearing again as soon as the harvest

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[10] The birds of Maine, p. 378, 1908.
[11] The Auk, vol. 7, p. 239, July, 1890.
[12] The Auk, vol. 16, p. 362, October, 1889.
[13] The birds of Ontario, 2d ed., p. 299, 1894.
[14] U. S. Agricultural Report, 1865–66, p. 42.
[15] Economic relations of Wisconsin birds: Geol. Surv. Wisconsin, vol. 1, 1873–79, p. 534.

was over. Damage of this character is of very sporadic occurrence as shown by the present stomach examinations. No trace of buds or grain was found in any of the stomachs, as would have been the case had bud and grain-eating habits been general with the species.

Conclusions.—From the examination of 243 stomachs it is evident that seeds of various conifers afford the red crossbill its chief sustenance throughout the year. Other food is taken either incidentally, as weevil larvae found within the seeds of pine, or because coniferous seeds are not readily available. As these crossbills destroy no crops and do not feed to any extent upon insects either beneficial or injurious, they are of little economic importance. The only apparent source of damage would be found in the bud-eating habit, and from the results obtained in this investigation, appreciable injury of this kind seems a remote possibility. The red crossbill may well be afforded protection because of its interesting ways and its presence at a time of year when bird life is scarce.

Food items of the red crossbill, identified to the genus or species, as determined by the examination of 243 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Pinaceae.	
Pinus strobus (white pine)	2
Pinus virginiana (scrub pine)	52
Pinus echinata (shortleaf pine)	1
Pinus ponderosa (western yellow pine)	36
Pinus resinosa (red pine)	8
Pinus sp. (pine)	100
Pinaceae—Continued.	
Picea engelmanni (Engelmann spruce)	1
Picea sp. (spruce)	3
Larix sp. (larch)	1
Tsuga canadensis (hemlock)	5
Cyperaceae.	
Scirpus sp. (bulrush)	1
Ambrosiaceae.	
Ambrosia elatior (ragweed)	1

ANIMAL FOOD.

Cicindelidae (tiger beetles).	
Cicindela sp	1
Vipionidae (parasitic wasps).	
Microbracon sp	1

WHITE-WINGED CROSSBILL (*Loxia leucoptera*).

(PLATE II.)

The white-winged crossbill is a bird of more northern distribution and appears more rarely and irregularly within the borders of the United States than the preceding species. It closely resembles the red crossbill in habits and general appearance, the most noticeable difference being the two white wing-bars which give to this bird its name. It usually appears in small flocks. Occasionally the two species are found flocking together.

Fifty-two stomachs were available for the study of the food habits of the white-winged crossbill; but as over half of these were collected in two widely separated localities in February and September, the material is very unequally distributed geographically and seasonally. For this reason no attempt is made to ascertain monthly percentages and the entire number is treated as a unit. Of the total contents of these 52 stomachs 6.88 per cent is animal matter and 93.12 per cent vegetable.

Vegetable food.—Arthur H. Norton reports by letter that this bird feeds on seeds of hemlock and spruce, but that he failed to see it alight in pine trees, although this tree is abundant; nor did he find pine seeds in stomachs. Other ornithologists, however, include pine among the coniferous seeds eaten by this crossbill.

As in the case of the red crossbill, conifers furnish the bulk of the food supply, 76.21 per cent of the total stomach contents being seeds of such trees. Curiously enough, spruce (*Picea*) and hemlock (*Tsuga canadensis*) furnished the bulk of coniferous seeds that could be identified. No pine seed was found in a condition to be recognized; but as nearly 24 per cent of the food was entered as unidentified "coniferous seeds," the probabilities are that a part of this was pine seed. Seventeen birds taken in February had eaten hemlock to the extent of nearly half their food, the remaining 50 per cent being coniferous seeds not further identified. Eleven birds collected in September had taken nothing but spruce. One October stomach was filled with the seeds of balsam fir (*Abies balsamea*), and one taken in November contained juniper berries (*Juniperus* sp.). As in the red crossbill, the variation in the character of the coniferous seeds in the diet seems to be geographical. The stomachs mentioned as containing largely hemlock were collected in a region where hemlock is the common conifer, and the same is true of those which were filled with spruce. It is probably this factor, rather than any aversion to pine seeds, that accounts for the lack of evidence that pine seeds contribute to the food of the species.

Two birds had made their entire meal on buds, which amounted to 3.84 per cent of the food. This is the only evidence found in the stomachs of either species of crossbill which indicates a bud-eating habit. One stomach, one-quarter filled with seeds of huckleberries (*Gaylussacia*) and crowberries (*Empetrum nigrum*), contained the only fruit eaten. Five birds had devoured weed seed to the extent of 9.61 per cent of the total food. Of these, three had made an entire meal on sunflower seeds (*Helianthus*), one had eaten ragweed (*Ambrosia*) to the exclusion of other food, and one had partaken equally of ragweed and foxtail grass (*Chaetochloa*). Vegetable rubbish and bits of unidentified seeds, amounting to 2.98 per cent, complete the list of vegetable food.

Animal food.—Animal food made up 6.88 per cent of the contents of the 52 stomachs and was composed of caterpillars and other larvae, 1.68 per cent, and an unidentified animal substance, 5.20 per cent. The latter was found in three stomachs collected in June in the same locality. Digestion was far advanced and the material was so finely comminuted that further identification was impossible. It was composed probably of fragments of pupal cases of some insect.

One of the few records of this crossbill eating freely of animal food is that of W. C. Fish,[16] who observed a large flock feeding on the larvae of the pitch-pine sawfly, *Diprion* (*Neodiprion*) *pinus-rigida*, which was very abundant at that time. According to his report the birds did their work so thoroughly that the pest was rare the next summer. C. J. Maynard [17] has found stomachs filled with

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[16] Packard, A. S., Insects injurious to forest and shade trees, p. 759, 1890.
[17] Coues, Elliott, New England bird life, vol. 1, p. 220, 1883.

cankerworms. Many other observers have recorded white-winged crossbills as feeding on the seeds of conifers and weeds; and the birds are also reported to have eaten frozen apples, but no evidence of this was found in the stomachs examined.

Conclusions.—It is apparent that the white-winged, as well as the red, crossbill depends to a large extent upon seeds of conifers for its sustenance throughout the year. The beak is especially adapted for extracting these seeds from the cones in which they grow, and it is probable that the bird could subsist entirely upon such food. In the great coniferous forests the eating of pine seed is of no economic importance, and as the few insects the bird eats are harmful the balance would seem to be slightly in its favor. The only source of complaint against the white-winged crossbill is found in the bud-eating habit, and in view of the comparative rarity of the species any injurious effect would be improbable even if buds furnished a far greater percentage of its diet than is shown by this study. So long as this bird continues as harmless in its food habits as at present known, it fully deserves the protection accorded it.

Food items of the white-winged crossbill, identified to the genus or species, as determined by the examination of 52 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Pinaceae.	
Picea sp. (spruce)	19
Tsuga canadensis (hemlock)	8
Abies balsamea (balsam fir)	1
Juniperus sp. (juniper)	1
Poaceae.	
Chaetochloa sp. (foxtail grass)	1
Empetraceae.	
Empetrum nigrum (crowberry)	1
Vacciniaceae.	
Gaylussacia sp. (huckleberry)	1
Ambrosiaceae.	
Ambrosia sp. (ragweed)	2
Asteraceae.	
Helianthus sp. (sunflower)	2

HOARY REDPOLL (*Acanthis hornemanni exilipes*).

Only 11 stomachs of this rare straggler from the north were available for examination, and 6 of these were from Fort Simpson, Canada. E. A. Preble[18] reported the hoary redpolls of this region as feeding on the seeds of dwarf birch (*Betula nana*), canoe birch (*Betula papyrifera*), and two alders (*Alnus incana* and *A. alnobetula* [=*sinuata*]). The six stomachs collected by Preble contained seeds of birch and alder. The remaining five from Michigan and Maine contained seeds of knotweed (*Polygonum*), stink grass (*Eragrostis*), sedge (*Carex*), pigweed (*Amaranthus*), and an unidentified seed.

The food of this redpoll probably differs little from that of the common redpoll (*Acanthis linaria*), which is discussed at greater length in the succeeding section.

[18] A biological investigation of the Athabaska-Mackenzie region: U. S. Dept. Agr., North Amer. Fauna No. 27, p. 418, 1908.

COMMON REDPOLL *(Acanthis linaria).*

(PLATE III).

The hardy little redpolls breeding in the far north and coming south into the United States only during the winter months may be readily recognized by their sparrow-like appearance and bright red cap. Usually a small percentage of the flocks show on their breasts more or less of the red that marks the adult males. These birds appear as irregular winter visitors in the Northern States; during some of the visitations they are very abundant.

For the study of this species 557 stomachs, collected in 15 States, Canada, and Alaska, were available. Of these, 550 were collected during the seven months from October to April inclusive, and the remaining 7 were scattered through the other five months.

The summer stomachs, collected in Canada, contained 25 per cent animal and 75 per cent vegetable food. The animal food consisted largely of spiders, ants, and flies, and the vegetable of seeds of various weeds and grasses. As the latter were the same as in the winter food, they will not be separately discussed.

Animal food is a negligible quantity during the winter months. One bird collected in March had eaten small cocoons (probably Tineidae) to the extent of 96 per cent of the food; and a second, taken in December, had made a meal on fly larvae and eggs of bugs. A few scattered fragments of other insects in various stomachs completed the animal food.

The vegetable food, 99.61 per cent of the total, consisted of weed seeds and seeds of birch and alder. The latter furnished the largest single item of food, 34.62 per cent of the total. A large series of stomachs from New Hampshire and a second series from Ontario contained little besides alder seeds. Various weed seeds amounted to 51.66 per cent of the food. Ragweed (*Ambrosia*), lambs-quarters (*Chenopodium*), pigweed (*Amaranthus*), smartweed (*Polygonum*), and catnip (*Nepeta cataria*) were taken most frequently. Ragweed is a favorite food of the species; it was found in 207 stomachs and amounted to 24.7 per cent of the total. The stomachs containing these seeds were collected in many localities throughout the Northern States and show that the birds feed on this weed wherever found. On the other hand, practically all the birch and alder seeds found in 185 stomachs were from only three places. Of the total food, 11.81 per cent consisted of seeds of lambs-quarters and 4.79 per cent seeds of pigweed. Seeds of grasses and a few other seeds, fruits, and rubbish composed the remainder of the food.

Food items of the common redpoll, identified to the genus or species, as determined by the examination of 557 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Poaceae.	
Chaetochloa viridis (green foxtail)	1
Chaetochloa sp. (foxtail grass)	9
Phleum pratense (timothy)	2
Panicum sp. (switchgrass)	1
Cyperaceae.	
Carex sp. (sedge)	4
Salicaceae.	
Salix sp. (willow) (buds)	3
Betulaceae.	
Betula sp. (birch)	110
Alnus incana (speckled alder)	4

Betulaceae—Continued.
Alnus sp. (alder) 103
Polygonaceae.
Eriogonum sp 40
Polygonum punctatum (smartweed) 1
Polygonum sp. (smartweed) 55
Chenopodiaceae.
Chenopodium album (lambs-quarters) 30
Chenopodium sp. (goosefoot) 132
Amaranthaceae.
Amaranthus sp. (pigweed) 65
Portulacaceae.
Portulaca oleracea (purslane) 7
Brassicaceae.
Campe sp. (wintercress) 4
Rosaceae.
Rubus sp. (blackberry) 1
Vacciniaceae.
Gaylussacia sp. (huckleberry) 1
Verbenaceae.
Verbena sp 1
Menthaceae.
Nepeta cataria (catnip) 29
Caprifoliaceae.
Viburnum sp. (blackhaw) 7
Ambrosiaceae.
Ambrosia elatior (ragweed) 18
Ambrosia sp. (ragweed) 189
Asteraceae.
Bidens sp. (Spanish needles) 1

PINE SISKIN (*Spinus pinus*).

(Plate III).

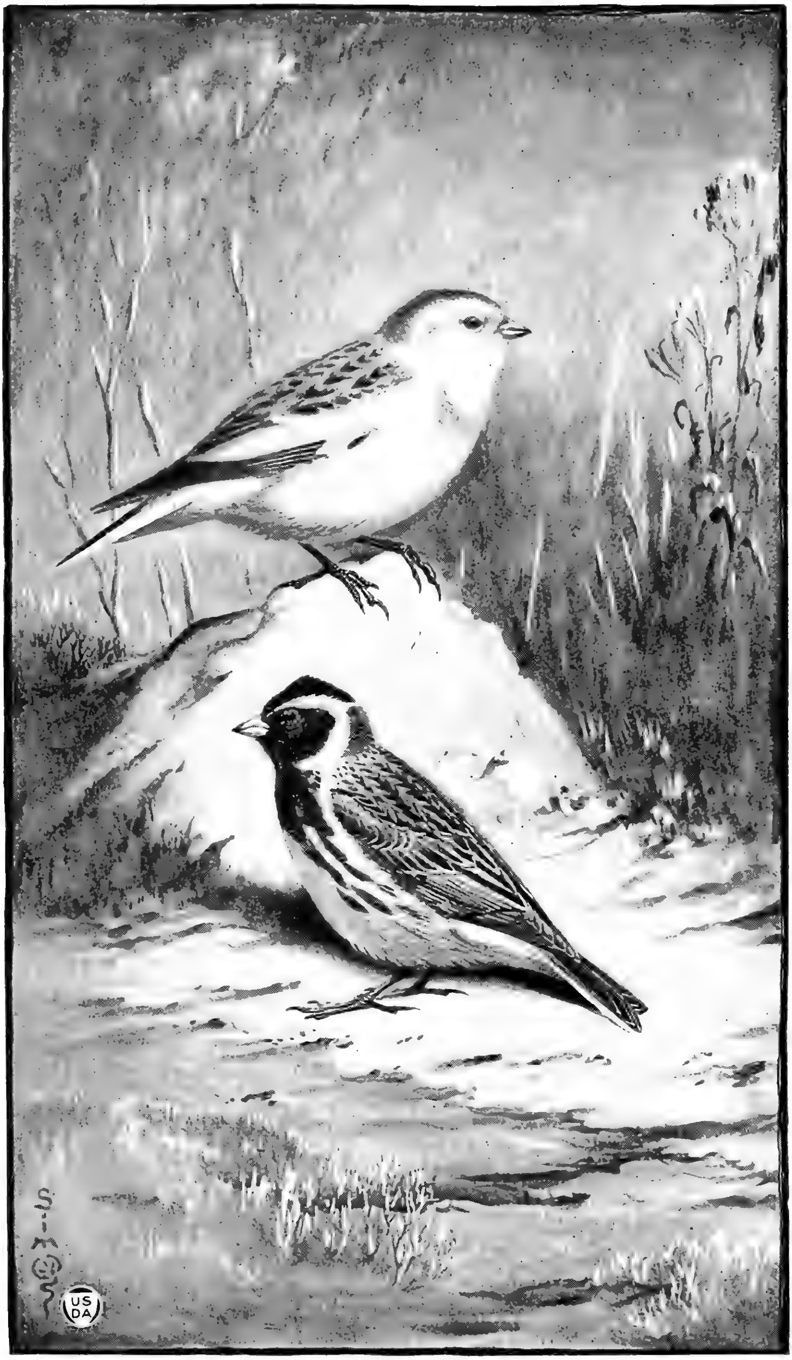
The pine siskin is another species best known to the people of the United States as an irregular winter visitor. Its dull streaked plumage and goldfinch-like flight are more or less familiar to observers throughout the country, though it is more common in the Northern States. It breeds chiefly in the great belt of coniferous timber of the Canadian Zone, which lies almost wholly beyond the borders of the United States, except in the mountains. In this country it breeds in northern Minnesota and Michigan, and in the mountains as far south as North Carolina in the East and to the Mexican border in the West.

For a study of the food of the pine siskin 291 stomachs from 20 States, the District of Columbia, and Canada were available. Of these, 266 were collected during the months from October to May, inclusive, this being the season during which the species is most common in this country; only 25 were taken during the remainder of the year.

Winter food.—Examination of stomachs taken during the winter months shows that seeds of conifers, alder, birch, and of weeds of various kinds are the principal food of the pine siskin at this season. Seventy stomachs contained coniferous seeds to the extent of 23.28 per cent of the season's food. Siskins, in common with many other seed-eating birds, usually make an entire meal on a single food, and consequently seeds of conifers constituted 100 per cent of the contents of nearly all stomachs in which they occurred. Forty-eight birds were found to have eaten birch or alder seeds practically to the exclusion of all other foods. In many stomachs distinction between these two kinds of seeds could not be made in the fragmentary condition in which they were usually found. Of the winter's food 18.69 per cent consisted of seeds of these two plants. Seventy-six birds had eaten weed seed, which comprised 24.58 per cent of the season's food. In the Eastern States ragweed (*Ambrosia elatior*), found in 27 stomachs, was most commonly taken, while in California 28 birds had eaten seeds of groundsel (*Senecio*). Various other seeds were occasionally taken but rarely in any quantity.

B2340M

REDPOLLS, FEMALE AND MALE (UPPER FIGURES) AND PINE SISKIN (LOWER)



B2337M

SNOW BUNTING (UPPER FIGURE) AND LAPLAND LONGSPUR (LOWER)

The pine siskin hulled the seeds eaten more consistently than any other bird considered in this bulletin, and consequently 34 stomachs were found in which the hulled and finely divided seed fragments could not be identified. This material constituted the remaining 20.15 per cent of the 86.7 per cent of vegetable matter in the winter food.

Of the 13.3 per cent animal matter in the winter food, caterpillars, found in 17 stomachs to the extent of 7.31 per cent of the total, were the most important single item. Four November stomachs collected at Rockaway Beach, N. Y., were filled with tortricid larvae (leaf-rollers). Eleven birds, collected in various parts of the country in April and May, had fed chiefly or entirely on caterpillars, while six had taken plant-lice (Aphididae) to the extent of 1.38 per cent of the food. One California bird had eaten more than 300 plant-lice, which formed 42 per cent of the stomach contents. A bird taken in North Carolina during an outbreak of grain aphids had fed exclusively on them, 80 being counted. Two others had made 98 and 100 per cent of their food of plant-lice. The stomach contents of seven birds taken in one locality in California during March and April averaged 90 per cent black olive scales (*Saissetia oleae*), a very destructive pest of the olive. In March over 12 per cent of the total food was made up of this insect, and it constituted 2.17 per cent of the total food for the season. The remaining 2.44 per cent of insect food consisted of fragments of beetles, grasshoppers, and other insects.

Summer food.—The 25 stomachs collected in the four months from June to September came from widely separated localities, mostly from the mountainous regions of the West. Animal matter formed 28.08 per cent of the contents of these, and vegetable matter 71.92 per cent. Three birds had eaten plant-lice, which constituted 8.48 per cent of the food for this season; two, one of which had eaten nothing else, had taken caterpillars to the extent of 4.68 per cent of the food, and the remaining 14.92 per cent of animal matter consisted of spiders, bugs, fly larvae, weevils, and other insects.

Of the vegetable food, coniferous seeds formed 20 per cent, weed seeds 19.2 per cent, and miscellaneous plant matter from a number of stomachs in which the contents were very finely divided, 32.72 per cent.

Various seeds other than those found in the stomachs examined have been mentioned in ornithological literature as constituting part of the food of the pine siskin. Among these are seeds of sweetgum (*Liquidambar styraciflua*), willow (*Salix*), juniper (*Juniperus*), and plantain (*Plantago*). Buds also are occasionally eaten, this habit causing the only complaint recorded against the species. This occurred in 1886, when a large number of pine siskins appeared in one locality in Oregon and fed extensively on the buds of fruit trees. No other charges have been made against the species on this ground, so that it seems safe to assume that this is not a regular habit of the bird but a local occurrence caused by unusual conditions. Normally the siskins are rarely present in sufficient numbers to do extensive damage, even if the bud-eating habit were much more highly developed than is now apparent.

Conclusions.—The evidence from stomach examination is strongly in the pine siskin's favor. Buds are occasionally eaten locally, but the vegetable food appears to be made up largely of seeds of weeds and other noncultivated plants. In its destruction of aphids, scale insects, and caterpillars the bird renders such valuable service as to entitle it to higher rank economically than most of the species treated in this bulletin.

Food items of the pine siskin, identified to the genus or species, as determined by the examination of 291 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Pinaceae.	
Pinus virginiana (scrub pine)	2
Tsuga canadensis (hemlock)	37
Pseudotsuga mucronata (Douglas fir)	1
Poaceae.	
Chaetochloa sp. (foxtail grass)	1
Betulaceae.	
Betula sp. (birch) or *Alnus* sp. (alder)	46
Ulmaceae.	
Ulmus sp. (elm)	2
Polygonaceae.	
Polygonum sp. (smartweed)	1
Amaranthaceae.	
Amaranthus sp. (pigweed)	4
Silenaceae.	
Alsine sp. (chickweed)	3
Silene sp. (catchfly)	1
Portulacaceae.	
Montia sp. (water-chickweed)	2
Rosaceae.	
Rubus sp. (blackberry)	1
Fabaceae.	
Trifolium sp. (clover)	1
Geraniaceae.	
Erodium sp. (alfilaria)	7
Oleaceae.	
Syringa vulgaris (lilac)	1
Ambrosiaceae.	
Ambrosia elatior	27
Menthaceae.	
Nepeta cataria (catnip)	1
Asteraceae.	
Helianthus sp. (sunflower)	2
Senecio sp. (ragwort)	29

ANIMAL FOOD.

Coccidae (scale insects).	
Saissetia oleae (black olive scale)	7
Aphididae (plant-lice).	
Siphocoryne sp. (grain aphid)	1
Curculionidae (weevils).	
Phytonomus posticus (alfalfa weevil)	1

SNOW BUNTING (*Plectrophenax nivalis*).

(PLATE IV.)

The snow bunting, or snowflake, is an easily recognized winter sparrow in northern United States, the distinct black-and-white or brown-and-white appearance being totally unlike any other member of the family. It breeds in the far North and appears regularly in winter only in the Northern States, where it is often found associated in flocks with shore larks and longspurs.

Very little has been written concerning the food of the snow bunting, writers usually confining themselves to the statement that the bird is fond of weeds or grass seeds. Doctor Judd's account of the food of this bird[19] was based on an examination of 46

[19] The relation of sparrows to agriculture: U. S. Dept. Agr., Biol. Surv. Bull. No. 15, pp. 52–53, 1901.

stomachs collected in New York, Michigan, Wisconsin, and Ontario. He found that seeds of ragweed (*Ambrosia*), pigweed (*Amaranthus*), and grain formed the chief foods. The present report is based on the examination of 461 stomachs taken in 11 States, Alaska, and 5 Provinces of Canada, representing every month of the year. Of these, 418 were collected in the seven months from October to April inclusive, this being the period during which the birds appear in the United States. The 43 stomachs collected during the remaining five months came from the Pribilof Islands, northern Saskatchewan, northern Ontario, and northern Quebec.

The food of the snow bunting during the seven months in which it may be found in this country is designated in this bulletin as winter food, while that taken during the other five months of the year will be called summer food, although neither term is strictly accurate.

Winter food.—In the examination of the 418 stomachs collected during the winter period it was found that 3.42 per cent of the food was animal and 96.58 per cent vegetable. The animal food was taken exclusively in March, October, and November. One stomach taken in March contained five clover-root curculios (*Sitona hispidulus*), which formed 52 per cent of the contents. This, together with a few other beetle fragments in other stomachs, formed 0.88 per cent of the food in the 73 stomachs collected in this month. Fragments of caterpillars and bugs in three stomachs constituted 0.37 per cent of the food, while spiders, sowbugs, and miscellaneous animal matter in three stomachs formed 0.86 per cent of the food.

Of 24 birds collected in October, 7 had eaten animal food to the extent of 13.54 per cent of the total for the month. Two had eaten beetles to the extent of 0.21 per cent of the monthly food. One October bird collected in Labrador had eaten at least 60 dipterous larvae, which constituted the entire stomach contents. Two Ontario birds had each made 60 per cent of their meal on caterpillars, while another from the same locality had eaten nothing else. The insect food of the four last-mentioned October birds, together with that of three others which had taken small quantities, constituted 13.33 per cent of the monthly food.

Of 27 birds collected in November, 12 had taken animal food of various kinds in small quantities. Beetles formed 0.85 per cent of the food of these birds; other insects (chiefly caterpillars) made up 6.26 per cent, and spiders and miscellaneous animal matter 0.96 per cent, or a total of 8.07 per cent.

A large variety of seeds constituted the 96.58 per cent of vegetable food during the winter period. The character of this food varied with the locality rather than the season. Thus, a large number of birds collected in Wisconsin at various times over a number of years had all fed extensively on the seeds of foxtail grass (*Chaetochloa*), ragweed (*Ambrosia*), goosefoot (*Chenopodium*), and pigweed (*Amaranthus*). Birds collected on Shelter Island, N. Y., under similar conditions had fed extensively on grass seed; while a large number collected around Hudson Bay had fed largely on grasses of other species. A number of April birds from Saskatchewan had eaten little but seeds of sedge and wheat, the latter waste grain picked up about straw stacks.

Grass seeds of many species furnished the largest single item in the stomach contents of the 418 birds, 31.16 per cent coming from this source. Of this the seeds of yellow foxtail (*Chaetochloa lutescens*) and green foxtail (*Chaetochloa viridis*), both common weeds in cultivated farm lands, furnished 11.83 per cent. A large number of birds taken on Long Island and Shelter Island, N. Y., had fed freely on the seeds of sandgrass (*Triplasis purpurea*), which constituted 4.43 per cent of the food. Seeds of numerous other grasses, no one of which formed a large percentage, together constituted the remaining 14.90 per cent of grass seed.

Seeds of sedges found in many stomachs in moderate quantities formed 8.50 per cent of the food for this season. Seeds of various species of *Polygonum*, among which black-bindweed (*P. convolvulus*) and smartweed (*P. lapathifolium*) were most frequently found, constituted 3.72 per cent of the food.

Seeds of various species of goosefoot (*Chenopodium*), mostly of lambs-quarters (*C. album*), formed 5.48 per cent of the food, and those of pigweed (*Amaranthus*), 5.56 per cent. A large variety of other seeds, including a number which could not be identified but no one of which formed any considerable proportion of the whole, made up 11.46 per cent. Seeds of ragweed (*Ambrosia elatior*) were a favorite food and constituted 9.42 per cent of the total.

Wheat formed 13.09 per cent of the total food; and all other grains, including corn, oats, and barley, 4.72 per cent. From the conditions under which much of this was obtained it must have been largely waste grain. In April, 56.4 per cent of the total food consisted of grain, of which 41.01 per cent was wheat. This percentage is high because a series of 37 of the 64 birds collected for the month were taken while feeding on old stack bottoms, so that the stomachs contained little except grain. A considerable portion of the grain taken during other months was from birds collected under similar conditions and can not be held against the species.

The remaining 3.47 per cent is made up of unrecognizable vegetable débris, usually so finely ground as to make any attempt at identification useless.

Some of the various seeds were occasionally taken in large numbers. One March bird from Massachusetts had eaten 1,250 seeds of goosefoot (*Chenopodium*), 175 of pigweed (*Amaranthus*), 1 of ragweed (*Ambrosia*), and 12 grass seeds, while another from the same locality had its stomach and gullet packed with 2,000 seeds of goosefoot (*Chenopodium*), 12 of smartweed (*Polygonum*), 7 of *Ambrosia*, 2 of hair grass (*Paspalum*), 50 of wild mustard (*Brassica arvensis*), and 1 unidentified grass seed. A bird taken on Shelter Island, N. Y., had also eaten a large number of seeds, 720 *Chenopodium*, 1 *Amaranthus*, and 480 meadow fescue (*Festuca elatior*) seeds being identified. Birds from various localities which had eaten from 100 to 500 seeds were numerous.

Summer food.—The contents of the 43 stomachs collected from May to September consisted of 29.26 per cent animal matter and 70.74 per cent vegetable. Practically all these stomachs were taken on the shores of Hudson Bay and on the Pribilof Islands. Beetles, mostly *Chrysomela subsulcata*, constituted 3.79 per cent of the food. Other insects, fly eggs, pupae, and adults, particularly those of crane-

flies, were the most important animal food, 16 of the 43 birds having eaten them to the extent of 25.45 per cent of the food. Fragments of spiders furnished the remaining 0.02 per cent of the animal matter taken.

Grass seed formed 28.63 per cent; sedges, 7.02; seeds of smartweed (*Polygonum*), 0.23 per cent; goosefoot (*Chenopodium*), 0.93 per cent; ragweed (*Ambrosia*), 4.42 per cent; grain, 1.16 per cent; and a considerable variety of other seeds 28.35 per cent of the summer food.

Conclusions.—It would seem that very little can be said either for or against the snow bunting. During the season when the bird is in settled areas its animal food is of little consequence, and the eating of weed seeds is of no particular economic importance. However, the bird does no harm and may well continue to receive the protection now accorded it.

Food items of the snow bunting, identified to the genus or species, as determined by the examination of 461 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Najadaceae.	
Najas flexilis (bushy pondweed)	1
Najas sp. (pondweed)	9
Poaceae.	
Syntherisma sanguinalis (crabgrass)	1
Syntherisma ischaemum (crabgrass)	1
Paspalum setaceum (hairgrass)	1
Paspalum sp. (hairgrass)	2
Echinochloa crusgalli (wild millet)	3
Panicum capillare (witchgrass)	5
Panicum virgatum (switchgrass)	3
Chaetochloa lutescens (yellow foxtail)	58
Chaetochloa viridis (green foxtail)	117
Phleum pratense (timothy)	8
Sporobolus vaginaeflorus (dropseed)	5
Sporobolus neglectus (dropseed)	10
Ammophila arenaria (beachgrass)	7
Avena sativa (oats)	21
Triplasis purpurea (sandgrass)	33
Festuca rubra (red fescue)	1
Festuca elatior (meadow fescue)	3
Agropyron repens (quackgrass)	5
Hordeum sp. (barley)	14
Triticum aestivum (wheat)	90
Poaceae—Continued	
Elymus sp. (wild rye)	9
Zea mays (corn)	4
Cyperaceae.	
Scirpus sp. (bulrush)	21
Carex sp. (sedge)	74
Juncaceae.	
Juncus sp. (rush)	4
Myricaceae.	
Myrica carolinensis (northern bayberry)	1
Polygonaceae.	
Rumex sp. (dock)	1
Polygonum lapathifolium (smartweed)	63
Polygonum pennsylvanicum (smartweed)	2
Polygonum convolvulus (bindweed)	13
Chenopodiaceae.	
Chenopodium album (lambsquarters)	74
Salsola kali (saltwort)	1
Amaranthaceae.	
Amaranthus sp. (pigweed)	87
Silenaceae.	
Arenaria peploides (sandwort)	3
Silene acaulis (moss campion)	1
Silene latifolia (bladder campion)	1
Portulacaceae.	
Montia fontana (water-chickweed)	1
Portulaca sp. (purslane)	3
Ranunculaceae.	
Ranunculus sp. (buttercup)	11

Brassicaceae.	
Brassica arvensis (wild mustard)	2
Rosaceae.	
Potentilla sp. (cinquefoil)	21
Rubus sp. (blackberry)	4
Fabaceae.	
Trifolium sp. (clover)	5
Empetraceae.	
Empetrum nigrum (crowberry)	13
Vitaceae.	
Parthenocissus quinquefolia (Virginia creeper)	1
Haloragidaceae.	
Hippuris vulgaris (bottle-brush)	3
Ericaceae.	
Ledum sp. (Labrador-tea)	2
Vacciniaceae.	
Vaccinium sp. (blueberry)	1
Verbenaceae.	
Verbena sp	2
Scrophulariaceae.	
Pedicularis sp. (lousewort)	4
Ambrosiaceae.	
Ambrosia elatior (ragweed)	165
Asteraceae.	
Bidens sp. (Spanish-needles)	1

ANIMAL FOOD.

Delphacidae (frog-hoppers).	
Stenocranus sp	1
Carabidae (ground-beetles).	
Pterostichus sp	2
Amara sp	2
Hydrophilidae (water scavenger beetles).	
Cercyon haemorrhoidalis	1
Histeridae (shining carrion-beetles).	
Hister sp	1
Aegialitidae (beach-beetles).	
Aegialites californicus	1
Scarabaeidae (dung-beetles).	
Aphodius distinctus	2
Chrysomelidae (leaf-beetles).	
Chrysomela subsulcata	5
Curculionidae (weevils).	
Sitona hispidulus (clover root-borer)	2

LAPLAND LONGSPUR (*Calcarius lapponicus*).

(PLATE IV.)

Breeding far to the north, usually beyond the tree limit, the Lapland longspur comes south in winter to the northern United States. It appears more or less commonly in the States north of the Ohio and Potomac Rivers, but in greatest numbers in the northern Plains States. In its far northern summer home the males are rather conspicuously dressed, having a black throat and breast and a rather bright rufous nape added to the usual sparrow garb. In winter the male wears a plumage similar to that of the female, a sparrowlike back of black and browns, and white underparts more or less streaked with brown or black. In any plumage it may be distinguished from most other sparrows by the elongated hind claw.

Little has been written regarding the food of this species other than Judd's account,[20] based on the examination of 113 stomachs. The present study comprises 656 stomachs (including those used by Judd) collected in 15 States, Alaska, and 5 Provinces of Canada during every month of the year. As in the discussion of other species considered in this bulletin, the data on food have been divided roughly into winter and summer categories, the winter division corresponding roughly with the months during which the species is found within the United States and the summer months including only the time spent in the northern home. Owing to the rather prolonged stay of the Lapland longspur in this country the eight months from October to May, inclusive, are considered as winter months

[20] The relation of sparrows to agriculture: U. S. Dept. Agr., Biol. Surv. Bull. No. 15, pp. 54–55, 1901.

and the remaining four, represented by 56 stomachs collected in Alaska and northern Canada, are discussed as summer months.

Winter food.—Unfortunately over half the 600 stomachs used in the study of winter food were collected in Kansas under very similar conditions. They were all taken in January and February and tend to give undue prominence to millet and crabgrass, the seeds of which constituted over 75 per cent of the January food and over 65 per cent of that eaten in February. As the millet was all waste grain picked up in the stubble, this high proportion of a grain can not be held against the bird.

Only 3.97 per cent of the food for the eight winter months consisted of animal matter and nearly half of this was taken in April by four birds that had fed almost exclusively on carabids of the genera *Platynus*, *Amara*, and possibly others. The remainder consisted of chrysomelids, weevils, fly larvae, caterpillars, and spiders taken in varying quantities in every month except February.

Of the 96.03 per cent of vegetable food, 61.73 per cent is represented by grass seeds of various kinds, 30.56 per cent being the seeds of foxtail (*Chaetochloa lutescens* and *C. viridis*) eaten commonly by birds from all parts of the country. Cultivated millet (*Setaria italica*), a closely related plant, contributed 10.01 per cent of the food. The seeds of these grasses are comparatively large, easy to obtain, and plentiful, and the birds make the most of them.

Seeds of crabgrass (*Syntherisma sanguinalis*) formed 8.66 per cent of the food, but most of them had been eaten by birds collected in one locality in Kansas. Seeds of various species of witchgrass (*Panicum*) made up 2.25 per cent of the food, and other grasses, among which crabgrass (*Syntherisma ischaemum*), wild millet (*Echinochloa crusgalli*), and goosegrass (*Eleusine indica*) were frequently taken, furnished 10.51 per cent of the total.

Sedges of various species had been eaten to the extent of 10.25 per cent of the food, chiefly by birds taken in Montana, Ontario, and Northwest Territories. Seventeen birds taken in October had eaten sedge seed to the extent of 64.42 per cent of the food, while over 8 per cent of the subsistence for the months of April and May was from this source. Seeds of purslane (*Portulaca*) were common in the food, but being such small seeds they made only 0.82 per cent of the bulk. Seeds of pigweed (*Amaranthus*) were freely eaten, 6.03 per cent of the total coming from the various species of this genus; and 6.49 per cent consisted of miscellaneous weed seed, among which goosefoot (*Chenopodium*) and ragweed (*Ambrosia*) were most common.

Wheat formed 8.33 per cent of the food and was eaten in every one of the eight months except October. Three birds collected while feeding on a newly sown field had eaten seeds of timothy and wheat, and it is possible that the species may do some damage by picking up newly sown grain or grass seeds. Other grain, chiefly oats, and all of it waste, had been eaten to the extent of 1.41 per cent of the food. Fragments of grass and unidentified vegetable débris made up the remaining 0.97 per cent of the food.

Summer food.—The food of the 56 birds collected in the months from June to September in Alaska or northern Canada consisted

of 47.43 per cent animal and 52.57 per cent vegetable matter. Beetles, mostly chrysomelids and weevils, made up 11.91 per cent of the summer food. Fly remains, almost entirely the eggs and adults of crane-flies (Tipulidae), constituted 17.77 per cent. The remaining 17.75 per cent animal food consisted of caterpillars, spiders, bugs, and fragments of other insects.

Grass seeds formed 12.02 per cent of the summer food; seeds of sedges, 4.16 per cent; and those of a variety of other plants, 27.86 per cent. No one of these had been taken consistently enough to make a large proportion of the total. The remaining 8.53 per cent consisted of bits of grass and unidentified vegetable débris.

Conclusions.—While in the United States, the Lapland longspur can not be said to be either strongly beneficial or injurious. The number of insects eaten is insignificant, but the bird is entitled to credit for whatever good it may do by eating weed seed. The bird's fondness for millet and other grass seeds might make it a nuisance were it not for the fact that it is rarely in the country when millet is sown or harvested.

Food items of the Lapland longspur, identified to the genus or species, as determined by the examination of 656 stomachs.

[The figures indicate the number of stomachs in which the items were found.]

VEGETABLE FOOD.

Poaceae.	
Syntherisma sanguinalis (crab-grass)	228
Syntherisma ischaemum (crab-grass)	26
Echinochloa crusgalli (wild millet)	11
Panicum capillare (witch-grass)	8
Chaetochloa lutescens (yellow foxtail)	19
Chaetochloa viridis (green foxtail)	66
Setaria italica (millet)	266
Phleum pratense (timothy)	4
Ammophila arenaria (beach-grass)	1
Avena sativa (oats)	17
Eleusine indica (goosegrass)	6
Triplasis purpurea (sand-grass)	1
Eragrostis sp. (love grass)	1
Festuca rubra (red fescue)	1
Hordeum sp. (barley)	1
Triticum aestivum (wheat)	55
Zea mays (corn)	1
Cyperaceae.	
Scirpus sp. (bulrush)	8
Carex sp. (sedge)	33
Polygonaceae.	
Polygonum lapathifolium (smartweed)	10
Polygonum convolvulus (bindweed)	1
Chenopodiaceae.	
Chenopodium album (lambs-quarters)	19
Amaranthaceae.	
Amaranthus retroflexus (pigweed)	1
Amaranthus spinosus (pigweed)	9
Silenaceae.	
Arenaria peploides (sandwort)	2
Silene sp. (campion)	1
Portulacaceae.	
Portulaca oleracea (purslane)	104
Ranuculaceae.	
Ranunculus sp. (buttercup)	10
Papaveraceae.	
Papaver macounii (poppy)	1
Rosaceae.	
Potentilla sp. (cinquefoil)	6
Fragaria sp. (strawberry)	1
Empetraceae.	
Empetrum nigrum (crowberry)	3
Violaceae.	
Viola langsdorfii (violet)	4
Cornaceae.	
Cornus canadensis (bunchberry)	6
Vacciniaceae.	
Vaccinium sp. (blueberry)	1
Gentianaceae.	
Gentiana sp.	1

Verbenaceae.		Ambrosiaceae.	
Verbena sp.	10	*Ambrosia elatior* (ragweed)	17
Caprifoliaceae.		Asteraceae.	
Symphoricarpos sp. (snowberry)	1	*Helianthus* sp. (sunflower)	9

ANIMAL FOOD.

Carabidae (ground-beetles).		Curculionidae (weevils).	
Amara sp.	2	*Sitona hispidulus* (clover-root curculio)	1
Platynus sp.	3	*Lophalophus inquinatus*	8
Silphidae (carrion-beetles).		Anthomyiidae.	
Silpha opaca	1	*Fucellia* sp. (kelp fly)	1
Scarabaeidae (dung-beetles).		Ichneumonidae (parasitic wasps).	
Aphodius inquinatus	3	*Pterocormus* sp.	1
Chrysomelidae (leaf beetles).		Agelenidae (spiders).	
Chrysomela subsulcata	2	*Tegenaria derhami*	1
Altica sp.	1		

SMITH LONGSPUR (*Calcarius pictus*).

Only 30 stomachs of the Smith longspur were available for examination. Of these 21 were collected in Illinois in April and 9 at Fort Simpson, Northwest Territories, during May. This number is not large enough to afford data as to the general nature of the food of the species, but when these stomachs and those of Lapland longspurs collected in the same localities during the same months are compared, the feeding habits of the two appear very similar. In these 30 stomachs 37.1 per cent was animal matter and 62.9 per cent vegetable.

The nine birds taken at Fort Simpson had all been feeding almost exclusively on insects, while those taken in Illinois had fed nearly to the same extent on seeds. Carabids of various species were found in 12 stomachs and formed 21.2 per cent of the food. Six birds had eaten click-beetles, which constituted 3.7 per cent of the food. Other beetles had been taken to the extent of 0.93 per cent of the food. Caterpillars, eaten largely by the birds from Illinois, formed 7.47 per cent; other insects (chiefly grasshoppers and crickets), 3.53 per cent; and spiders, 0.27 per cent of the total.

Seeds of long-leaved rush grass (*Sporobolus asper*) had been eaten largely by a number of Illinois birds and formed 28.67 per cent of the total food. As with the Lapland longspur, seeds of various grasses seem to be sought, since, in addition to the *Sporobolus*, 12.07 per cent of the food was foxtail (*Chaetochloa lutescens* and *C. viridis*), 7.33 per cent witchgrass (*Panicum*), and 4.73 per cent the seeds of various other grasses, making grass seeds total 52.8 per cent of the food. Weed seeds, chiefly ragweed (*Ambrosia elatior*), constituted 1.63 per cent of the total; wheat, 4.67 per cent; barley, 0.67 per cent; and vegetable débris, 3.13 per cent.

Food items of the Smith longspur, identified to the genus or species, as determined by the examination of 30 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Poaceae.		Poaceae—Continued	
Syntherisma ischaemum (crabgrass)	1	*Echinochloa crusgalli* (wild millet)	2
Panicum capillare (witchgrass)	4	*Chaetochloa lutescens* (yellow foxtail)	16

Poaceae—Continued.	
Chaetochloa viridis (green foxtail)	2
Phleum pratense (timothy)	1
Sporobolus asper (dropseed)	14
Hordeum sp. (barley)	1
Triticum aestivum (wheat)	2
Eleusine indica (goosegrass)	3
Cyperaceae.	
Scirpus sp. (bulrush)	1
Carex sp. (sedge)	1
Fabaceae.	
Trifolium sp. (clover)	1
Euphorbiaceae.	
Euphorbia sp	1
Ambrosiaceae.	
Ambrosia elatior (ragweed)	3

ANIMAL FOOD.

Carabidae (ground-beetles).	
Amara sp	2
Platynus sp	1
Anisodactylus sp	3
Histeridae (shining carrion-beetles.	
Hister sp	1
Calandridae.	
Sphenophorus sp. (billbug)	1

CHESTNUT-COLLARED LONGSPUR (*Calcarius ornatus*).[21]

The chestnut-collared longspur breeds on the Plains from Kansas north into southern Canada and winters from Nebraska south into Mexico.

Only 40 stomachs of this longspur were available for examination, a number which is not large enough to furnish a basis for reliable conclusions regarding the food. Of these, 7 were collected in Texas in December, and the remaining 33 were taken in 6 States during the months from May to September, inclusive. Animal matter formed 31.05 per cent of the content and vegetable matter 68.95 per cent.

Coleoptera, chiefly leaf-beetles (Chrysomelidae) and weevils, had been eaten to the extent of 6.97 per cent of the total; but crickets and grasshoppers were the chief animal food, 13.08 per cent of the entire diet being from this source. Bugs (Hemiptera) formed 4 per cent, caterpillars and adult moths 5.7 per cent, other insects (largely ants) 0.93 per cent, and spiders 0.37 per cent of the total.

Grass seeds formed over half the vegetable food (35.48 per cent of the total), 4.1 per cent of which was witchgrass (*Panicum*) and the remainder a number of species in small quantities. A number of Montana birds had eaten wheat, 15.33 per cent of the food being from this source, while all other grains made 6.12 per cent of the food. Weed seed, chiefly goosefoot (*Chenopodium*) and pigweed (*Amaranthus*), formed 8.85 per cent of the total; 0.5 per cent was formed by unidentified seeds, and 2.67 per cent by vegetable débris.

Food items of the chestnut-collared longspur, identified to the genus or species, as determined by the examination of 40 stomachs.

[The figures indicate the number of stomachs in which the items were found.]

VEGETABLE FOOD.

Poaceae.	
Panicum capillare (witchgrass)	7
Panicum wilcoxianum (witchgrass)	1
Chaetochloa viridis (green foxtail)	2
Stipa sp. (feathergrass)	1
Sporobolus asper (dropseed)	2
Triticum aestivum (wheat)	7
Cyperaceae.	
Carex sp. (sedge)	1
Chenopodiaceae.	
Chenopodium sp. (goosefoot)	6
Amaranthaceae.	
Amaranthus sp. (pigweed)	3
Asteraceae.	
Helianthus sp. (sunflower)	4

[21] The chestnut-collared and McCown longspurs, while breeding largely in the United States, and not therefore winter visitants, are treated in the present bulletin in order that the published account of the food of the longspurs may be complete.

ANIMAL FOOD.

Acridiidae (grasshoppers).	
Melanoplus sp	1
Elateridae (wireworms).	
Limonius sp	1
Tenebrionidae (darkling-beetles).	
Blapstinus sp	1

McCOWN LONGSPUR (*Rhynchophanes mccowni*).[22]

The McCown longspur has a breeding and wintering range very similar to that of the chestnut-collared longspur. Little information is at hand regarding its food, as only 19 stomachs from four States and 1 from Saskatchewan were available for examination. All were collected in the months from April to October inclusive.

The following are the percentages of the various food items found: Beetles, largely weevils, 7.26; grasshoppers, 6.53; other insects, 5.79; grass seeds, 10; sedge seeds, 25.16; pigweed, 1.37; sunflower, 10.63; wheat, 15.53; other seeds, 16.16; and vegetable débris, 1.57. The total animal matter was 19.58 per cent and the vegetable matter 80.42 per cent.

Food items of the McCown longspur, identified to the genus or species, as determined by the examination of 19 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Poaceae.	
Chaetochloa viridis (green foxtail)	1
Bouteloua sp. (grama)	1
Stipa sp. (feathergrass)	1
Triticum aestivum (wheat)	4
Cyperaceae.	
Carex sp. (sedge)	6
Chenopodiaceae.	
Chenopodium sp. (goosefoot)	5
Amaranthaceae.	
Amaranthus sp. (pigweed)	4
Polygonaceae.	
Polygonum convolvulus (bindweed)	1
Boraginaceae.	
Lithospermum sp. (puccoon)	1
Ambrosiaceae.	
Ambrosia sp. (ragweed)	1
Asteraceae.	
Helianthus sp. (sunflower)	4

ANIMAL FOOD.

Scarabaeidae (dung-beetles).	
Aphodius sp	2

COMMON PIPIT (*Anthus spinoletta rubescens*).

(PLATE V.)

The common pipit, a small ground-loving bird, in appearance suggesting a warbler, breeds in the mountains and the far North and appears in varying numbers throughout most of the United States during migration and in winter. Examinations were made of 301 stomachs, of which 284 contained enough food to be used in this study. These were taken in 26 States, the District of Columbia, Alaska, and Canada, every month of the year being represented. Unlike the other birds thus far discussed in this bulletin, the pipit was found to be largely insectivorous, 84.67 per cent of its food being of animal origin and only 15.33 per cent vegetable.

[22] See footnote 21, on page 26.

Animal food.—Millipeds, crustaceans, and other miscellaneous animal matter constituted 1.58 per cent of the food; spiders, 6.03 per cent; and insects, 77.06 per cent. While neither all ground-beetles (Carabidae), 3.76 per cent of the food, nor all wasps, bees, and the like (Hymenoptera), 8.62 per cent, are beneficial, many of them are predacious or parasitic, and therefore useful. It is not to be overlooked, however, that approximately half of the Hymenoptera in the food of the pipit consisted of ants, the destruction of which is to be commended. The remaining insect food, 64.68 per cent, was taken for the most part from injurious groups, although a few water beetles and neuropterous insects of more or less neutral economic significance were included.

Beetles were present in the food more than any other order of insects, totaling 23.51 per cent and divided among the various groups with the percentages indicated, as follows: Ground-beetles (Carabidae), 3.76; leaf-beetles (Chrysomelidae), 2.78; leaf-chafers and dung-beetles (Scarabaeidae), 3.14; weevils, 7.48; and other Coleoptera and coleopterous larvae, 6.35. Lepidopterans were the next largest item in the pipit's food, amounting to 15.41 per cent, the bulk of which was caterpillars. About half the 8.62 per cent formed by the Hymenoptera consisted of ants, and the remainder of small parasitic forms. The true bugs (Hemiptera) formed 3.64 per cent of the total food; grasshoppers and crickets (Orthoptera), 9.16 per cent; and flies and their larvae (Diptera), 10.97 per cent. The remaining 5.75 per cent in the insect food consisted of various insects, such as caddisflies, stoneflies, and other neuropterans.

The study of the food of the pipit reveals the interesting fact that the bird does its best work in the destruction of injurious insects during the winter months, when it feeds extensively on white grubs (scarabaeid larvae) and weevils. A large part of the latter are cotton-boll weevils (*Anthonomus grandis*) taken in December, January, and February in Louisiana and Texas. Thirty-six pipits had eaten these weevils, one having taken nine. As these were hibernating individuals the pipits were attacking the species at the time when its numbers are at the lowest point. The elimination of individuals at this period does far more good than the destruction of the same number during the summer. White grubs are also regularly eaten while the pipits remain in the South, being found in each of 33 stomachs.

In studying the food in detail, it is found that in 65 stomachs collected in January, carabids formed 0.46 per cent; leaf-beetles (Chrysomelidae), 2.08 per cent; white grubs (Scarabaeidae), 15.69 per cent; weevils, almost entirely cotton-boll weevils, 12.58 per cent; other beetles, 5.12 per cent; caterpillars, 5.2 per cent; ants and small parasitic Hymenoptera, 2.8 per cent; true bugs (Hemiptera), almost entirely the large nymphs of cicadas, which one would think entirely too large for so small a bird to eat, 10 per cent; grasshoppers and crickets, 11.84 per cent; flies, 1.55 per cent; other insects, 0.88 per cent; spiders, 5.8 per cent; and other animal matter, 3.43 per cent.

The most marked changes in the diet occurring during February are a decrease to 7.67 per cent in the white grubs eaten and an in-

D1277M

PIPIT

crease in weevils to 17.58 per cent. No Hemiptera were taken, although they formed a tenth of the food during the previous month.

During March the white grubs formed an insignificant portion of the diet (1.31 per cent) and the weevils dropped over half, to 7.38 per cent. In May the white grubs and their allies formed 5.38 per cent of the food, owing to the taking of adults rather than larvae, and they were not an important article in the diet for the remainder of the year. The weevils also steadily decreased until during the summer very few were eaten. In September, however, the pipits were feeding on them again, and during the last four months of the year the quantity taken fell below 10 per cent only in November, when it amounted to 8.42 per cent.

The percentage of caterpillars eaten also fluctuates considerably, May with 31.46 and September with 32.77 being the high months, although they were taken freely all summer. Most of the Hymenoptera were taken during July and August, when 44.5 per cent and 33.18 per cent respectively were recorded. These figures are undoubtedly abnormally high, because a few of the birds from Colorado and Wyoming fed almost entirely on these insects. Too few stomachs were available during the summer months to give definite results, although both Orthoptera and Diptera were eaten freely. The maximum occurred in April, when many crickets were eaten; and the maximum for Diptera, in June, when fly larvae of various kinds were taken regularly. Three birds had eaten mites (Acarina); and one, insects of the family Psocidae, forms not usually eaten by birds.

Vegetable food.—In the vegetable food of the pipit, seeds of various grasses formed 4.06 per cent of the total; various weed seeds, 8.04 per cent; grain, all of which was taken in the winter months, 1.72 per cent; and vegetable débris, 1.51 per cent. No vegetable food was taken during May, June, and July and very little in April, August, and September. In January it was made up of the seeds of various grasses (9.32 per cent), chiefly crabgrass (*Syntherisma sanguinalis*), and seeds of several species of spurge (*Euphorbia*), 8.38 per cent. Grain gleaned from the stubble fields formed 3.54 per cent, and fragments of grass and other vegetable débris constituted the remaining 1.33 per cent. In December 51 per cent of the food was vegetable, the highest point for the year. From this month it falls rapidly away, reaching zero during the summer.

Conclusions.—From the foregoing it is evident that the pipit injures no crops, the only count against it being its destruction of a few ground beetles and parasitic hymenopterans. The remainder of its food is of a neutral or distinctly beneficial nature. It is especially worthy of note that this species does its best work during the winter months, when the consumption of insects by many other birds is at its lowest. At this time the pipit maintains a steady diet of white grubs and cotton-boll weevils, two of the worst pests in the South. The bird can hardly be commended too highly and deserves complete protection at all times.

Food items of the common pipit, identified to the genus or species, as determined by the examination of 301 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Pinaceae.	
Pinus palustris (longleaf pine)	1
Poaceae.	
Syntherisma sanguinalis (crabgrass)	32
Syntherisma ischaemum (crabgrass)	6
Brachiaria platyphylla	1
Panicum capillare (witchgrass)	10
Panicum fasciculatum (witchgrass)	1
Panicum sp (witchgrass)	4
Chaetochloa lutescens (yellow foxtail)	3
Chaetochloa sp. (foxtail)	9
Paspalum sp. (hairgrass)	1
Avena sativa (oats)	1
Dactyloctenium aegyptium (Egyptian grass)	5
Eleusine indica (goosegrass)	3
Hordeum sp. (barley)	1
Triticum aestivum (wheat)	3
Zea mays (corn)	2
Cyperaceae.	
Scirpus sp. (bulrush)	1
Carex sp. (sedge)	5
Polygonaceae.	
Rumex sp. (dock)	5
Polygonum opelousanum (smartweed)	1
Polygonum sp. (smartweed)	5
Chenopodiaceae.	
Chenopodium sp. (goosefoot)	4
Amaranthaceae.	
Amaranthus sp. (pigweed)	19
Portulacaceae.	
Calandrinia sp. (rockpurslane)	4
Corrigiolaceae.	
Scleranthus annuus (knawel)	1
Silenaceae.	
Alsine sp. (chickweed)	7
Ranunculaceae.	
Ranunculus sp. (buttercup)	1
Brassicaceae.	
Brassica sp. (wild mustard)	1
Hamamelidaceae.	
Liquidambar styraciflua (sweetgum)	1
Fabaceae.	
Trifolium sp. (clover)	4
Geraniaceae.	
Erodium sp. (alfilaria)	1
Violaceae.	
Viola langsdorfii	1
Rutaceae.	
Zanthoxylum sp. (prickly-ash)	1
Euphorbiaceae.	
Croton sp. (goatweed)	1
Acalypha virginica (Virginia copperleaf)	2
Chamaesyce serpyllifolia (spurge)	7
Chamaesyce sp. (spurge)	32
Empetraceae.	
Empetrum nigrum (crowberry)	1
Verbenaceae.	
Verbena sp.	1
Rubiaceae.	
Diodia teres (buttonweed)	1
Caprifoliaceae.	
Sambucus canadensis (elder)	1
Ambrosiaceae.	
Ambrosia elatior (ragweed)	1
Ambrosia sp. (ragweed)	1
Asteraceae.	
Helianthus sp. (sunflower)	1
Deinandra sp. (tarweed)	2
Madia sp. (tarweed)	1
Centaurea sp. (knapweed)	2

ANIMAL FOOD.

Acridiidae (brown grasshoppers).	
Chortophaga viridifasciata	1
Melanoplus sp	1
Locustidae (green grasshoppers).	
Ceuthophilus sp	1
Gryllidae (crickets).	
Gryllus assimilis	3
Nemobius sp.	2
Scutelleridae (shield-bugs).	
Camirus porosus	2
Homaemus parvulus	1
Cydnidae (negro-bugs).	
Thyreocoris sp	1
Aethus sp	1
Pentatomidae (stink-bugs).	
Thyanta custator	1
Thyanta sp	1
Dendrocoris sp	1
Coreidae.	
Corizus sp	1
Lygaeidae.	
Nysius sp. (false chinch bug)	4

Lygaeidae—Continued	
Blissus leucopterus (chinch bug)	2
Geocoris punctipes	3
Geocoris bullatus	2
Geocoris sp	8
Sphaerobius quadristriatus	1
Ligyrocoris sp	1
Reduviidae (assassin-bugs).	
Atrachelus cinereus	1
Nabidae.	
Nabis sp	12
Miridae (plant-bugs).	
Irbisia sericans	1
Lygus sp	1
Membracidae.	
Stictocephala sp	1
Bythoscopidae (leafhoppers).	
Agallia 4-punctata	1
Agallia sp	1
Cicadellidae (leafhoppers).	
Oncometopia lateralis	1
Helochara communis	1
Draeculacephala mollipes	2
Xerophloea viridis	2
Deltocephalus sp	1
Athysanus sp	1
Cicadula sp	1
Empoasca sp	1
Delphacidae (frog-hoppers).	
Liburnia sp	1
Cicindelidae (tiger-beetles).	
Cicindela sp	2
Carabidae (ground-beetles).	
Bembidium sp	1
Elaphrus sp	1
Notiophilus sp	2
Pterostichus sp	1
Amara sp	4
Philophuga sp	1
Harpalus sp	1
Anisodactylus sp.	1
Agonoderus sp.	3
Tachys incurvus	1
Haliplidae (crawling water-beetles).	
Haliplus triopsis	1
Peltodytes callosus	1
Peltodytes sp.	1
Hydrophilidae (water scavenger-beetles).	
Enochrus nebulosus	1
Enochrus sp.	1
Staphylinidae (rove-beetles).	
Stenus callosus	1
Stenus sp.	9
Atheta sp.	1
Oxytelus fuscipennis	1
Histeridae (shining scavenger-beetles).	
Hister sp.	1
Elateridae (wireworms).	
Lacon rectangularis	1
Monocrepidius vespertinus	2
Monocrepidius sp	5
Latridiidae.	
Melanophthalma sp.	1
Coccinellidae (ladybird-beetles).	
Coccinella trifasciata	1
Hippodamia convergens	3
Hippodamia sinuata	1
Hippodamia ambigua	1
Hippodamia sp.	1
Scymnus sp.	1
Tenebrionidae (darkling-beetles).	
Blapstinus sp.	10
Scarabaeidae (dung-beetles).	
Onthophagus tuberculifrons	2
Onthophagus sp.	1
Aphodius fimetarius	4
Aphodius fossor	1
Aphodius distinctus	5
Ataenius figurator	1
Chrysomelidae (leaf-beetles).	
Calligrapha sp.	1
Graphops sp.	4
Myochrous denticollis (corn-leaf beetle)	34
Prasocuris vittata	1
Phaedon prasinella	1
Paria quadriguttata	1
Galerucella sp.	1
Monoxia sp.	1
Cerotoma trifurcata (bean leaf-beetle)	2
Chaetocnema confinis	1
Chaetocnema denticulata	1
Chaetocnema irregularis	1
Chaetocnema opacula	2
Chaetocnema sp	14
Systena taeniata	2
Systena elongata	2
Systena sp	6
Longitarsus montivagus	1
Microrhopala sp	1
Coptocycla sp	2
Otiorhynchidae (weevils).	
Phyxelis rigidus	5
Eudiagogus pulcher	1
Tanymecus confertus	2
Otiorhynchus ovatus (strawberry crown girdler)	3
Thricolepis inornata	1
Graphorhinus vadosus	1
Curculionidae (weevils).	
Sitona hispidulus (clover-root curculio)	18
Sitona californicus	1
Sitona flavescens	9
Sitona sp	7
Lophalophus inquinatus	2
Lepyrus sp	1
Phytonomus sp	1
Hyperodes sp	1
Anthonomus grandis (cotton-boll weevil)	36
Baris sp	4
Baropsis cribratus	1
Nicentrus sp	1
Rhinoncus sp	9
Chalcodermus aeneus (cow-pea-pod weevil)	1
Chalcodermus sp	2

Curculionidae—Continued.	
Tyloderma foveolata	3
Cylindrocopturus sp	1
Calandridae.	
Sphenophorus sp. (billbug)	4
Calandra oryzae (rice weevil)	1
Borboridae.	
Limosina sp	1
Oscinidae (frit-flies).	
Hippelates sp	1
Vipionidae (parasitic wasps).	
Apanteles sp	1
Braconidae (parasitic wasps).	
Chelonella fissus	1
Ichneumonidae (parasitic wasps).	
Mesochorus sp	1
Campoplex sp	3
Lissonota sp	1
Exolytus sp	1
Ichneumonidae—Continued.	
Agrothereutes sp	1
Phaeogenes sp	1
Pterocormus sp	3
Diapriidae.	
Galesus sp	1
Formicidae (ants).	
Solenopsis sp	4
Myrmica sp	4
Lasius sp	2
Formica subsericea	1
Formica sp	4
Halictidae (sweat-bees).	
Chloralictus zephyrus	1
Chloralictus sp	3
Attidae (jumping spiders).	
Zygoballus sp	1
Zonitidae (land snails).	
Zonitoides musculus	1

SPRAGUE PIPIT (*Anthus spraguei*).

The Sprague pipit breeds in the Great Plains region and is very similar in appearance and habits to the common pipit. Only 11 stomachs were available for examination, so that little can be stated regarding the food. In six stomachs over 75 per cent of the food consisted of grasshoppers or crickets, while 2 were well filled with seeds of goatweed (*Croton*) and spurge (*Euphorbia*). Ants and other small hymenopterans, weevils, and various other beetles, small bugs, and caterpillars formed the remainder of the food.

Food items of the Sprague pipit, identified to genus or species, as determined by the examination of 11 stomachs.

[*The figures indicate the number of stomachs in which the items were found.*]

VEGETABLE FOOD.

Poaceae.	
Panicum sp. (witchgrass)	1
Cyperaceae.	
Carex sp. (sedge)	1
Euphorbiaceae.	
Croton sp. (goatweed)	2
Euphorbia sp. (spurge)	1
Boraginaceae.	
Lithospermum sp. (puccoon)	1
Ambrosiaceae.	
Ambrosia sp. (ragweed)	1

ANIMAL FOOD.

Scutelleridae (shield-bugs).	
Phimodera torpida	1
Pentatomidae (stink-bugs).	
Euschistus sp	2
Coreidae.	
Alydus sp	1
Lygaeidae.	
Nysius sp. (false chinch bug)	5
Carabidae (ground-beetles).	
Anisodactylus sp	1
Malachiidae.	
Collops quadrimaculatus	2
Chrysomelidae (leaf-beetles).	
Graphops beryllinus	1
Graphops sp	1
Glyptoscelis sp	1
Chaetocnema sp	1
Curculionidae (weevils).	
Pachyphanes discoideus	1
Smicronyx vestitus	1
Ceutorhynchus sp	1
Rhinoncus sp	1
Formicidae (ants).	
Formica sp	2